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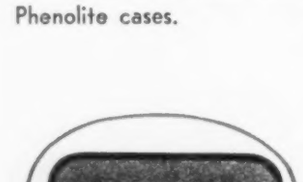

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MOELLER INSTRUMENT COMPANY
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RICHMOND HILL , NEW YORK

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Instruments
THE MAGAZINE OF Measurement and Control

Vol. 14 DECEMBER 1941 No. 12

FRONT COVER: Petroleum refinery instrumentation—Ashland Oil & Refining Co., Ashland, Ky.
Courtesy Leeds & Northrup Co.

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1942: Fight and Work for Freedom

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Chapter III—A-c. Wattmeters 394
Chapter IV—Comparison of the A-c. Types 404
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MANUFACTURERS' NEW LITERATURE ..... (Insert)

ADVERTISERS' INDEX ..... (Insert)

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RICHARD RIMBACH, Managing Editor
M. F. BEHAR, Editor

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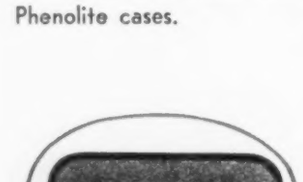

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

1942: Fight for Freedom and Toil for Freedom

FOREWORD—Your editor is a Reserve officer, at present classified as essential in his various civilian occupations, but ready for active service in the Armed Forces. Next month's editorial is already written but the situation changes so rapidly . . .

IN times of peace it was gratifying to know that many readers make it a habit to read this page first—and that some of you won promotions and pay raises as a result. Even in times of peace, though, you did not use to read this page from purely selfish motives. Every good American prefers Team-work, is a Boy Scout at heart and loves to serve the U.S.A. Of all good Americans, none is better than the measurement-minded . . . the one with a keen sense of true values . . . you! In letters and conversations you have expressed heartier praise for editorials preaching unselfish service than for editorials on how to get ahead.

This is being written on Thursday, December 11, 1941—just two weeks before the Birthday of the Prince of Peace . . . and just four days after war-crazy yellow beasts swooped down on peace-loving Americans attending Sunday morning Divine Services. This is being written exactly twenty-three years and one month after we in the A.E.F. heard the cease-firing order which interrupted, but did not end, the conflict between Decency and Schrecklichkeit. Now that the shooting-war aspect of the conflict between Americanism and paganism has been resumed, you will look to this page to help you help win the war. Well, for eight years this page has been helping you help win *this* war! Ever since I became editor in June 1933 I have been preaching Team-work and Industrial Mobilization more often than I discussed scientific and technological matters. These editorials could be reprinted into a book for your information *without changing a single word*, but there would be so many repetitions that it will best serve your convenience to print only brief extracts from only a few of them—the "prophetic" ones. (ALL pro-instrumentation preachments, of course, by Preparedness preachers like me or by Nazis—in *Instruments* or elsewhere—have contributed to Defense—whether or not meant to do so.)

In the following extracts, not a word is changed and the words originally emphasized by *italics* are kept so; but **bold-face type** is used in addition, to emphasize passages of present and permanent interest. My very first message as your new editor (June 1933) preached Team-work:

. . . To be sure, the millenium has not arrived. . . . Sales engineers . . . still number in their midst a few "promise-anything-to-get-the-order" sinners. Manufacturers still print a few exaggerations. And some users still display cynicism and intolerance toward the most ethical of those who try to serve them . . . Get together! Show your cards! Ask and answer all relevant questions! Don't hold out! . . . Above all, don't nurse grudges. If you think you have a grievance, get it off your chest, talk it over with the other fellow . . . That wonderful lubricant known as the milk of human kindness.

We are all colleagues in one esteemed profession: All men who invent, design, build, sell, specify, apply, install, service and maintain measuring instruments, meters and automatic control equipment belong to one fraternity. . .

July 1933 (just after Hitler stole the reins of control from old Hindenburg's feeble hands):

. . . Here and there on the face of the globe, now and then in the course of the centuries, governments change with startling suddenness . . . The fundamentals of measurement and control are as true in government, in sociology and in economics as in industrial instrumentation. To control conditions effectively, it always is necessary to measure them: "First measurement, then control."

The trouble with some leaders and with their henchmen is that (as instrumenticians would put it) they control by brute force and disregard factors which, inhering in each human "application," spell the doom of their schemes.

Lenin and Hitler provide two extreme examples of *force majeure* control thus doomed to failure. Lenin's utopia—communism—is predicated upon men and women utterly devoid of the desire for acquiring private possessions. Such a State may be kept going for years with the aid of brute force but it cannot endure unless the men and women in it become angels. On the other hand, **Hitlerism is predicated upon the "wolf-pack" thesis**—upon all men and women always finding joy in robbing and starving to death whatever brothers and sisters are designated as "enemies." This mode of control, likewise, cannot attain stability until **the Nazi plan of abolishing Christianity** is accomplished.

All tyrannies resemble faulty-control applications where excessive power consumption is required to prevent the process running wild. Similarly, their oversize power cylinders (police forces) and elaborate wirings (spy systems) cannot achieve correct regulation: on the contrary, these inevitable features of despot control set up such stresses that the whole equipment eventually goes haywire . . . Every fanatical ruler either mistakes his tyranny for true regulation, or else cares nothing about it as long as he commands the power.

What can we do about it? Obviously, first of all spread the idea of a stable control of human affairs . . . Our methods of instrumentation, if applied to human institutions, would result in efficient "non-hunting" control with minimum energy consumption and maximum satisfaction to all. . .

Though supporting our President's National Defense policies, I frequently assailed "New Deal" persecutions of Technology and Industry. August 1933:

When . . . rulers in Washington make serious errors of judgment, when they slip up altogether . . . we deem it our duty to register an indignant protest. . . .

Of all creators of future employment, research workers are the most effective. . . . Of all publicly maintained research institutions, the Bureau of Standards is the most useful. . . . What in the name of common sense is the idea of throwing out of work hundreds of this nation's most useful work-creators as part of a program of putting idle men to work? . . . A stupid error. . . . It seems that there is a "blind spot."

and January 1934:

Whatever device diminishes the sum total of drudgery—of repetitive labor tending to sharpen one faculty at the expense of all others—is a blessing. Don't use fewer such devices, as some politicians advocate; use more of them! . . .

Increasing the purchasing power of farmers and other favored groups, "soaking the rich," and other palliatives, cannot change the laws of economics. We repeat: don't use fewer

The Counter Reads 0 0 1 6 8

and thereby registers the end of the fourteenth year of *Instruments*' service to users of measurement and control devices—service to the

UNITED STATES OF AMERICA

The entire staff of *Instruments* wishes you

A Merry Christmas and a Happy New Year

instruments designed to cut down the labor content of your products; install *more* of them to expand your business and give work to more men.

By 1935, the increase in the number of Goebbels and Himmler agents in this country clearly meant that Hitler was starting to make war on us. So on Army Day (April 6) I took Washington's famous saying, "In time of peace prepare for war" as the text for my April editorial:

"IN TIME OF PEACE . . ."

Since Hitler upset the European apple-cart . . . **the world is sitting on a TNT shell with its percussion fuze armed. . . .** We think it timely . . . to devote this column to solemn reminders:

1. When war breaks out among Great Powers we shall be drawn in.
2. War is likely to break out soon in Europe, Africa and the Far East.
3. Modern warfare is . . . a struggle in which each side strives to utilize the coördinated power of every individual and every material resource.
4. **It requires a minimum of eighteen months for a nation whose engineers, industrial executives, . . . are untrained for their parts in an emergency, to mobilize its resources against aggression.**
5. In less than eighteen months such a nation can be . . . decisively conquered. . . .
6. In the First World War, America was forced to *extemporize* methods of directing the industrial effort. . . .
7. This huge task cannot be accomplished . . . without greater support from all industries. Up to now, relatively few manufacturers have assembled the fixtures, gages and other facilities . . .; few have devoted sufficient time to industrial preparedness.
8. . . . From now on, it will require self-sacrificing patriotism for industrial technicians and executives to prepare to serve America—at their own expense! This is precisely what we earnestly urge you to do! Get in touch with the nearest Army or Navy technical district office; fill out a list of your qualifications; enroll; and start training!
9. If you prefer joining a munitions preparedness movement without having to enroll in the Army or Navy Reserves, join the Army Ordnance Association (Mills Bldg., Wash'n).

December 1935:

It is becoming plainer that more than one selfish agitator is inflaming the rabble against labor-saving devices (and against private ownership thereof) in an attempt to become a dictator. Curious to know our enemies' tactics, we have listened to their broadcasts and read their manifestos. . . .

. . . The would-be Hitlers claim that *because* we have emerged from the covered-wagon age it has become possible for a few plutocrats to own nearly everything and *therefore* we must kill, jail or otherwise dispose of the plutocrats, abolish our form of government . . . and give supreme power to **Mr. X or Doctor Y or Father Z**—who of course would somehow "distribute the wealth." . . . Of course! . . . Somehow! . . . These jobs are in "privately-owned" establishments. What of it? Under communism or fascism there would be even fewer overlords, exercising a far more despotic power without the possibility of tripartite governmental regulation.

September 1936 editorial, *entirely* devoted to a plea that Congress give the U.S. Navy $3,500,000 to build a model basin, began as follows:

In a world where **"might-makes-right" nations tear up treaties and arm for aggression on peace-loving peoples,** our security depends in large measure upon constant naval, merchant-marine and seaplane engineering advances. . . . **Germany, Japan and Italy,** in the order named, now have the world's biggest model basins. . . .

April 1937 editorial on same lines as April 1935. Specifically endorsed Sheppard-Hill industrial mobilization bill:

. . . The enactment of this bill would do more to keep America at peace than all the schemes of **so-called pacifists whose real aim is to disarm our nation. . . .** Patriotic readers will do well to write or wire their Senators and Representatives—and, in any event, to join the Army Ordnance Association, the organization "pledged to industrial preparedness for war as our nation's strongest guarantee of peace."

July 1937 editorial was a reprint—by request of patriots—of December 1935 editorial on hate-inciting "Mr. X or Doctor Y or Father Z."

In April 1939, four months were yet to pass before the snake struck, but it was plain to see that he was poised to strike at Free Europe before striking at America. So:

"IN TIME OF WAR"

You probably don't remember our April 1935 and April 1937 editorials preaching Industrial Preparedness. You may recall, however, that each was entitled "In Time of Peace. . . The word "peace" was technically true although **the gangster governments had already begun, four years ago and two years ago, making war on the United States through spies, through hate-sowing "American citizens" and through training camps on our own soil.**

On this 1939 Army Day, we need no longer refrain from using the correct word in the title. . . . We believe our most urgent duty is to recommend something *every one* of you can do immediately. . . . It is that you do your own job more thoroughly than ever. Your job (in nine cases out of ten) is to cut down the sum total of drudgery involved in America's industrial production. . . . Use instruments more extensively and effectively than ever; and **defend America by defending your labor-saving methods and devices against enemy agents.**

May 1939. Title, "World of To-morrow" (N. Y. World's Fair):

. . . Millions will view the inspiring exhibits; many will rid themselves of hate-germs; will realize that the better tomorrow is being built by today's Invention and Research.

June 1939. Title, "Dangers from Within":

. . . fear for the future of Technology's progress—a fear based on the realization that powerful, close-to-the-White-House, prophets of "technological unemployment" who themselves are not technicians, are gradually succeeding in **converting to their beliefs some technically-trained men**—not only youths or weaklings but even . . . successful men who ought to hold fast to the credo that has for its first article "Automatization Makes Jobs."

August 1939:

. . . In the last five years or so there has been a growing disparity between the rate of installation of instruments and the rate of training of instrument men of all classes. Many engineers whose duties involve the selection and supervision of instruments now take pride in calling themselves instrument engineers. . . . Imminent fulfillment of the prediction which once aroused ridicule: **"I confidently predict . . . instrument courses in the majority of technical schools . . . a nation-wide Society . . . and all the panoply of an established, organized, esteemed profession."**

October 1939. Title, "For the Good of the Nation."

Instrumentation makes jobs. . . . By creating new industries which largely supplant competitive imports. . . . By creating new industries which tend to **relieve our dependence on strategic and critical materials.**

April 1940:

Our industries could eventually produce the equipment of a mechanized and motorized force adequate to meet a major emergency; but most facilities are so unprepared to produce such matériel that in the event of **a sudden emergency (the only kind nowadays)** they would find themselves under alien masters before they could get started.

Instruments readers can render effective service by doing their own work: by constantly extending the fields of industrial instrumentation. . . . Specifically, automatic gaging of items required in large quantities is the most crying need—and is one of the industrial preparedness problems which *Instruments* readers are well qualified to solve.

June 1940:

Every great emergency has caught our peace-loving American people unprepared . . . America's immediate problem is to transform her potential power into actual ready-to-use power. . . . Production . . is impeded by an acute shortage of . . . specialists. . . . For years we have urged that technical schools give basic Instrumentation courses. . . . The time has come to speak plainly. *We declare that it is the DUTY of American engineering schools to inaugurate thorough courses in Instrumentation NOW.*

Since then, as you know if you are not a new subscriber, the main theme of this page has been Speeding up Defense, and *that*, my dear colleagues, is what you can do best, through Instrumentation. As you help win this war, remember what Nazi propagandists here have tried to make us forget: America has never lost a war.

Come what may, *Instruments* will continue its service to you.

—MFB

Chicago Society for Measurement and Control

Automatic Control Valves will be discussed by C. E. Mason, of the Mason-Neilan Regulator Co., Boston, at the January meeting, Monday, Jan. 12, at the St. Clair Hotel, 162 E. Ohio St. Dinner (1.25) at 6:30, meeting at 8 sharp. Come to the meeting if not to the dinner. Carl Hope, Exec. Sec'y, 2626 W. 31st Blvd., Chicago.

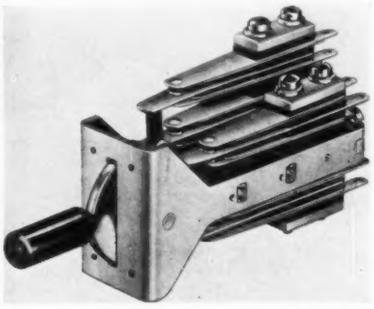
THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Heavy-duty Lever Switch

New "No. 4101" is a heavy-duty multiple-contact positive-action lever switch said to be "the first such switch to successfully provide positive action independent of contact springs." Announcement pictures six basic contact forms, any combination of



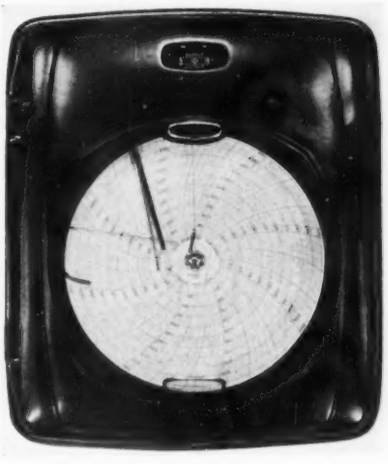
which may be made, so that the number of possible arrangements covers all switching requirements. Standard heavy-duty $\frac{3}{16}$" diam. silver contacts, 10 amps. 110 volts non-inductive a.c.; extra-heavy-duty ($\frac{5}{8}$") 20 amps.—*Donald P. Mossman, Inc., 6021 N. Northwest Highway, Norwood Park, Chicago, Ill.*

Ignitron Combination Welding Timer

Especially adapted for seam and spot welding where frequent changes of timing are necessary, new "SX" ignitron welding timer consists of a control panel and ignitron tube assembly mounted in a common enclosing cabinet. (Ignitrons are essentially mercury arc rectifiers with an ignitron or control electrode inside. Heat of the arc is removed by a water cooling system.) Seam weld "on" or "off" timing adjustable from 1 to 30 cycle steps is provided; one to 15 pulsations can be made for each setting. In operating, the electronic tubes and circuits perform five distinct functions: (1) "On" timing; (2) "Off" timing; (3) Pulsation counting; (4) Heat control; (5) Firing of the ignitron power tube. When the weld initiating switch is closed, a relay closes its contacts. At a predetermined point in the voltage cycle, corresponding to the power factor of the welding machine, the start tube in the "on" timing circuit is energized, and the ignitrons begin to conduct. At the end of the "on" time interval, the stop tube in that circuit becomes energized, and simultaneously the start tube in the "off" timing circuit is energized. At the end of the "off" time interval the whole sequence is repeated.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Air-operated Controller

In introducing new "Model 30" Stabilog Controller, makers emphasize that new features are principally refinements, for better appearance and still closer control, and that new model utilizes proven principles



of operation. Illustration shows principal outward change: new universal rectangular case. When panel-mounted, instrument extends only $\frac{3}{4}$" from panel surface. Door is recessed; hinges and hasp are flush with door surface. A dual pressure indicator replaces customary two small gages. Interior illumination is readily provided when desired. All operating adjustments are made from front of case, the adjusting mechanisms for change of control point, throttling range, and reset resistance being immediately accessible when door is opened. But entire operating mechanism is protected and concealed behind a removable plate. Unit construction simplifies replacement of measuring system, changing type of control mechanism, or any other major servicing. *Operating features:* (1) Proportional function, providing uniform pneumatic proportional action, adjusted to the smallest value that will result in stabilization following a disturbance of process conditions. (2) Reset function acts simultaneously with proportional function, establishing stabilization at desired point of control. Third function provides a temporary additional correction, determined by rate of change in any disturbance of conditions: if rate of change is fast, additional correction is large; if rate of change is slow, additional correction is negligible. Operation of this third function is automatic, being governed by the proportional and reset adjustments.—*The Foxboro Co., Foxboro, Mass.*

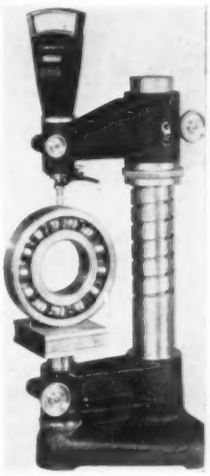
Sealed Voltmeter Resistors

Two new types of "Sealed Precision Voltmeter Multiplier Resistors" are specifically designed for severely humid conditions such as marine service; are absolutely watertight (unaffected by the salt immersion test). They are exceptionally rugged and meet all dimensional requirements of existing government specifications. "Type

MFA," 8-13/16" long, is available in resistance ranges of 3.5, 4.0, 4.5 and 5.0 megohms with corresponding voltage ratings of 3.5, 4.0, 4.5 and 5.0 kv., respectively. "Type MFB," 4-5/16" long, is available in ranges of 1.0, 1.5, 2.0, 2.5 and 3.0 megohms, and 1.0, 1.5, 2.0, 2.5 and 3.0 kv. respectively.—*International Resistance Company, 401 North Broad St., Philadelphia, Pa.*

Dial Gage for Large Work

New "Heavy-duty Model 8 Comparitol," designed to handle heavy precision work up to 8" diam., is a measuring and inspection instrument which eliminates human "feel" and skill from the making of close-tolerance inspections. A knife-edge lever system is used in the mechanism. New model has a $2\frac{1}{2}$" diameter column, extremely heavy holder bracket to hold the measuring head and a 4" × 4" hardened steel, accurately lapped table to handle large work. Rigid base has three-point contact for extreme stability. "Comparitols" are being used to check and inspect plug gages, bearings, pins, ball bearings and other parts. New model may be obtained with scale reading to 0.0001" or 0.00005". Not being affected by vibration, it may be used under shop conditions where shock from machinery or instability of floors would make the use of standard inspection instruments impossible, it is said.—*George Scherr Co., 128 Lafayette St., New York City.*

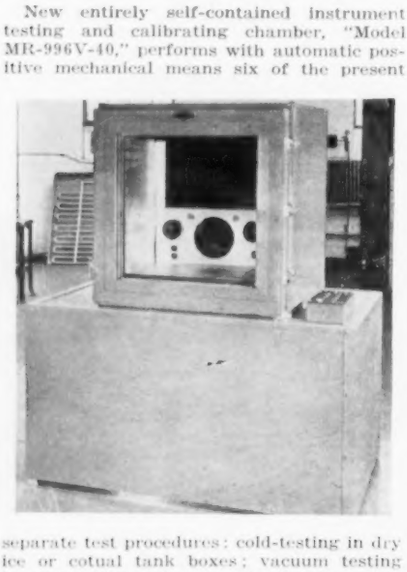


Portable Wireless Alarm

"Watchman's Protector" is a new alarm system wherein a watchman or guard carries a small device known as "The Walking Stick" and, in the event of trouble, pushes an inconspicuous button on handle of "stick," thereby sending a special "key" radio signal which operates an alarm. This in turn sounds a siren, etc., or privately warns other guards, police, etc.—*Rowe Radio Research Laboratory Co., 4201 Irving Park Blvd., Chicago, Ill.*

Temperature-altitude Test and Calibration Chamber

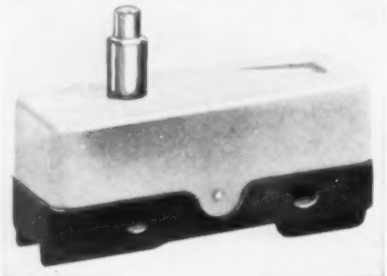
New entirely self-contained instrument testing and calibrating chamber, "Model MR-996V-40," performs with automatic positive mechanical means six of the present



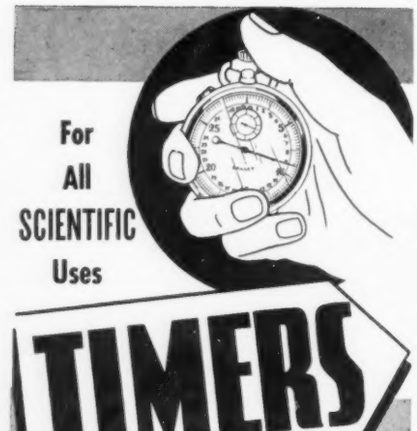
separate test procedures: cold-testing in dry ice or cotual tank boxes; vacuum testing in manometer racks; heat testing in resistance chambers; humidity tests in spray or steam tanks; and vibration and radiomatic affection check-ups. Test temperatures are automatically maintained at pre-selected points in a range from +158°F. to —76°F. It is said that humidity limitations within physical range are fully controlled. Neutral and separate vacuum lines as well as auxiliary electric circuits and a coaxial cable are standard equipment. Although largely custom built for special use, certain sizes have been standardized for armament and instrument calibration for U. S. Army Air Corps and the producers of instruments. Optional accessories include built-in manometers, recording thermometers, special micrometers (controllable from outside the cabinet) and stroboscope apparatus for observing wear and lubrication problems in bearings at speed conditions. This instrument is also suitable for studying plastics, and for testing parts such as diaphrams and bellows.—*Mobile Refrigeration, Inc., 10 Rockefeller Plaza, New York City.*

Overtravel Type Precision Switch

In new "Overtravel Type Acrosnap Switch," overtravel of at least 1/16" is provided, though the extent used for actuation remains at 0.001" as in maker's standard pin plunger type. All other features are as in pin plunger switch and include novel



"rolling spring" principle (see *Instruments*, August 1941, page 222). Condensed specifications: 10 amp. 115 volt a.c., 5 amp. 250 volt a.c., 3 amp. 450 volt a.c., max. wattage 1000 for all three. Pressure, 3 oz. to 14 oz. Weight, approx. 1 oz. Size—1-15/16" × 11/16" × 27/32". Large shank on button for added strength.—*Acro Electric Co., 3180 Fulton Rd., Cleveland, Ohio.*



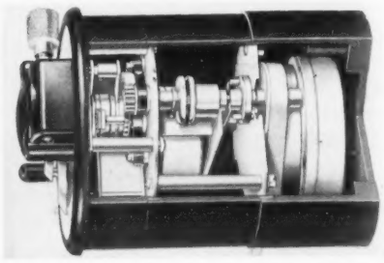
CHRISTMAS SEALS

Protect Your Home from Tuberculosis

TRU-VAC
VACUUM GAUGES
(PIRANI TYPE)
Priced From $39.50
Circular on Request.
CONTINENTAL ELECTRIC CO.
GENEVA, ILLINOIS

Automatic Timers

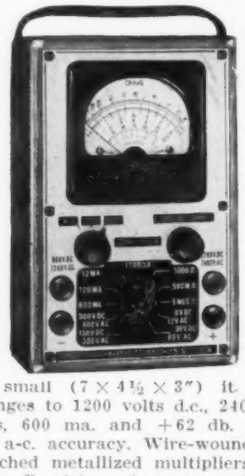
New Time Relays, "Type RS1C" and "Type TD1C," are synchronous-motor-operated timers which either keep an electrical circuit closed for a preset time interval or, in the case of the "TD1C," can be used as time delay relays which when energized



keep a circuit open for a selected interval. These timers have an instantaneous reset feature and when restarted they repeat the timing without manual resetting. They are available when inbuilt manual start button or can be supplied for remote control start button. Auxiliary contacts can be furnished for audible or visual signal circuits, etc. They are suitable for every kind of machinery or industrial process which must be time controlled or for electrical circuits where a time delay action is required. Clutch Construction: Two cup-shaped fine-toothed clutch members are actuated by a small electromagnet, the armature of which carries a leaf spring which serves as the actuating member. This assembly is counterbalanced with a second spring to absorb all shocks. By reason of the balance and the design of the clutch teeth (which require but little pressure to insure good reliable grip) a small force is sufficient to actuate the clutch, thereby minimizing wear and tear. Milled clutch teeth prevent slippage of clutch and yet provide quick and reliable disengagement. Setting Means: A micrometer adjusting knob with a fine worm gear moves a pointer across the dial at a slow rate. Visibility of the whole scale, and knife-edge pointer, permit accurate settings with little effort. Progress Indicator: An additional pointer rotates with the switch operating member and shows at all times how much of the cycle has elapsed or the time it takes before the switch trips. Main switch unit is a quick-make, quick-break type with silver contacts rated 10 amp. 115 v. or 5 amp. 220 v. or 3 amp. 440 v a.c. Available time scales from 0-15 sec. to 0-5 hr.—*The R. W. Cramer Co., Centerbrook, Conn.*

Multi-range Tester

New "Precision Series 832-A" is a 31-range a-c. d-c. tester said to be built to withstand abuse and rough handling.



Though small (7 × 4½ × 3") it incorporates ranges to 1200 volts d.c., 2400 a.c., 5 megohms, 600 ma. and +62 db. 2% d-c. and 3% a-c. accuracy. Wire-wound shunts and matched metallized multipliers of 1% accuracy.—*Precision Apparatus Co., 647 Kent Ave., Brooklyn, N. Y.*

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MERCURY COLUMN GAUGES

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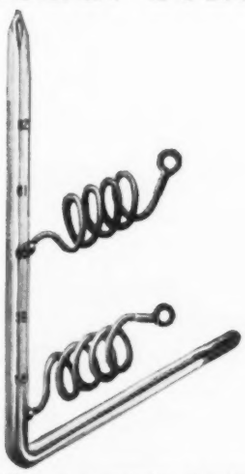
For Extremely Close
Temperature Control
Visual-Stats

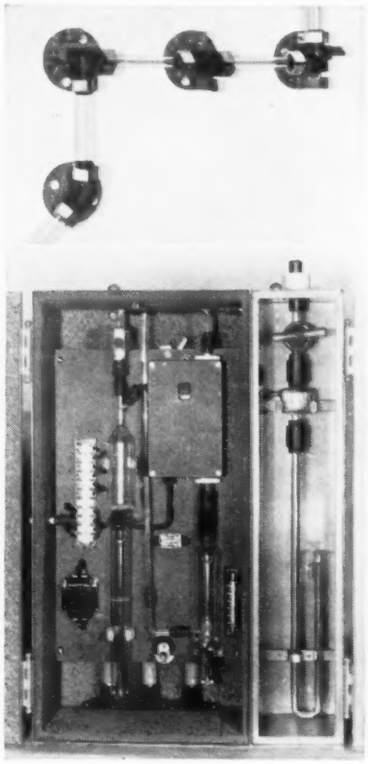


● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

The Philadelphia Thermometer Co.
915 Filbert Street -:- Philadelphia
Oldest Thermometer Manufacturer in Philadelphia

Improved CO_2 Recorder

In new Micromax CO_2 Recording Equipment, heavy-walled glass tubing brings the continuously flowing flue-gas sample from primary filter to cell assembly. Thus, flue-



gas sample comes in contact only with glass from the time it leaves the stack until it leaves the measuring cell. All-glass construction of sampling line and cell assembly entirely eliminates maintenance due to corrosion. In addition, the clear glass allows instant inspection of the sampling line. Should fly ash pass through the filter and lodge in the line, it can easily be seen and flushed out with water. The three-way cock and the condensate drain have also been changed to glass. Mounted in a separate compartment of the cabinet at the right of cell assembly, they are well protected.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.*

Tester for Coin-operated Amusement Devices

Designed for testing and servicing coin-operated amusement devices, new "Model 415" test instrument is 6" long, 3" wide

and 2⅜" high, weighs 24 oz., yet is capable of the full variety of measurements involved in servicing this type of equipment. —*Radio City Products Co., Inc., 88 Park Place, New York City.*

BAILEY METER CONTROL SYSTEM

The Mark of
Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

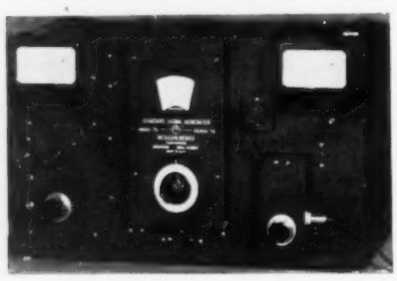
Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY
1041 Ivanhoe Rd., Cleveland, Ohio

Signal Generator

New "Model 75 Standard Signal Generator" is said to meet the increasing demand for a signal generator capable of making accurate measurements in the frequency range above 100 megacycles. Among features as described in announcement: (1)



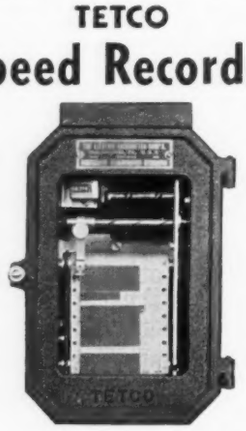
Highly stable resonant transmission line oscillator permits covering entire frequency range without switching. (2) Individually-calibrated direct-reading frequency dial with spiral scale approximately 5 ft. in length, plus 6000 division linear scale for selectivities. (3) Motor driven tuning dial. (4) Completely power line operated; built-in voltage regulator. (5) Heater of oscillator tube runs on d.c.: clean note at high frequencies. (6) 6-step 120 db. balanced resistance attenuator presents constant output impedance over the whole frequency and output range. Frequency range: 50 to 400 Mc. in one range. Output Voltage: Continuously variable from 0.2 microvolt to 0.2 volt, balanced to ground. Output Impedance: Constant, 36 ohms balanced, 18 ohms to ground. Modulation: Continuously variable to 50% from 400 and 1000 cycle internal oscillator or from external source. Built-in modulating amplifier. Panel 14" × 24", 14" deep over knobs. Weight approx. 90 lbs.—*Measurements Corporation, Boonton, N. J.*

Paper Size Tester

"Currier Size Tester" is said to provide an accurate as well as convenient means of testing paper for its degree of sizing. It is essentially a device for wetting one side of the paper sample and keeping it wet until enough water has penetrated sample so

that a circuit is completed and the end point is indicated. Distilled water is used as the wetting medium and, as the circuit enormously amplifies the current through the wetted sheet, the use of an electrolyte becomes unnecessary and a rational size test becomes possible. For special problems of liquid resistance to papers, in most cases the liquid itself may be used in the instrument in place of water.—*Thwing-Albert Instrument Co., 3323 Lancaster Ave., Philadelphia, Pa.*

TETCO
Speed Recorder



Creates a permanent time record on a waxed chart. Accurately records rate of production, time and duration of stops, total quantity produced

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for *coarse* and *fine* adjustment

Rex Rheostat Co.
3 FOXHURST ROAD, BALDWIN, L. I., N. Y.

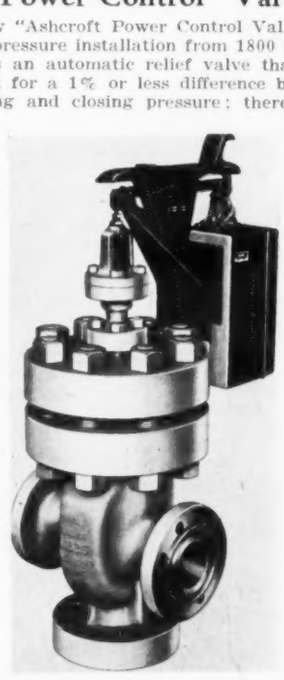
Full-wave Variable Voltage Transformer

New model is announced of the "Varitran," a variable voltage transformer capable of voltage adjustment in infinite steps with "perfect" regulation characteristics and "high" efficiency. Standard designs provide

an output voltage of 0 to 130 for 115 volt input. New model is designed for low voltage rectifiers, plating equipment, battery chargers, etc. An insulated secondary is provided with two contacts moving in opposite directions from the secondary center tap. In this way the d-c. voltage can be varied from zero to maximum, using only the one Varitran instead of a Varitran-Stepdown transformer combination.—*United Transformer Corp., 150 Varick St., New York City.*

"Power Control" Valve

New "Ashcroft Power Control Valve" for high-pressure installation from 1800 to 2500 lbs. is an automatic relief valve that may be set for a 1% or less difference between opening and closing pressure; thereby ef-



fecting saving over the 4% required for the spring-loaded safety valves. Announcement claims more accurately balanced boiler operation at peak loads, more uniform line pressure, reduced spring-loaded safety valve maintenance. *Operating principle:* Boiler drum or superheater outlet pressure or steam header pressure actuates a pressure control set at the popping pressure, which operates an electric contact on a difference in pressure of 1% or less. Current is transmitted to a solenoid which opens and closes the pilot valve. When it opens it unbalances the pressure over the main valve disk and it opens and remains open until the pilot valve is closed. Ashcroft Power Control Valve is not intended to replace the spring-loaded safety valve, but is a supplementary operating valve.—*Consolidated Safety Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport, Conn.*

Speed - - -

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Indicating Speed and Total Run.
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2525 NO. BROAD ST., PHILADELPHIA, PA.

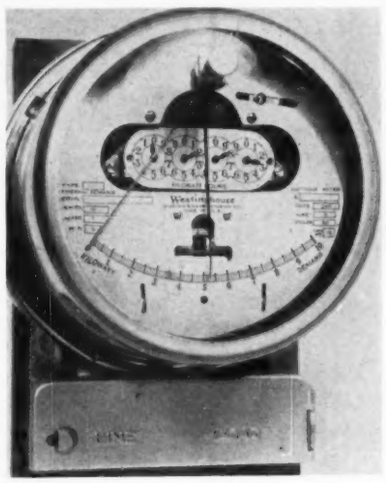
Illuminated Magnifier

Developed particularly for use in defense industries "Magni-ray," a new illuminated magnifier which plugs into standard 110-volt circuit, provides correct lighting direct-

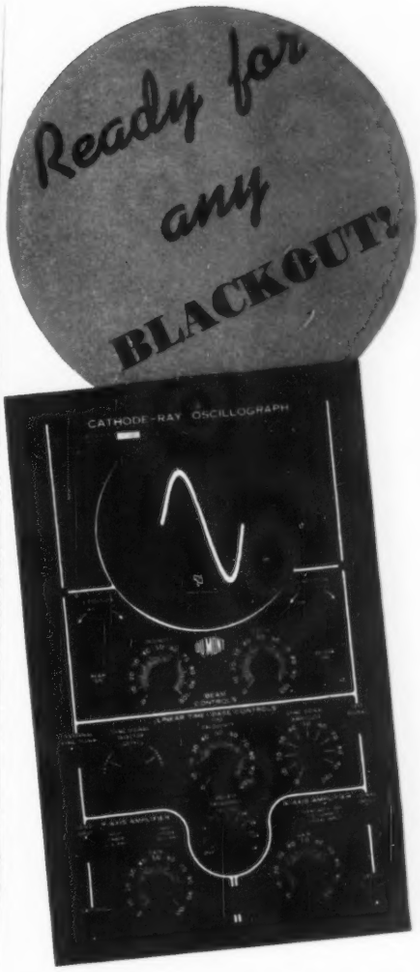
ly on the object in the field, is designed for detecting cracks, burrs and poor finish on small parts; also for setting of tools on precision machinery; also for reading fine dials and graduations, maps and recording instruments. It may quickly be removed from its stand and attached to a machine tool. "Magni-ray" is available in two types: 3" lens; and a specially designed 2" wide 3-power achromatic lens.—*George Scherr Co., 128 Lafayette St., New York City.*

Combination Watthour and Thermal Demand Meter

Developed to meet extension of demand rates to smaller loads, new low-cost combination watthour and thermal demand meter is available (for the first time) in standard house size, case and mounting. With a-c. ratings of 5-, 15-, and 50-amp.



capacities, 120 to 240 volts, 2- and 3-wire for reading up to 20 kw., unit is similar to the ordinary watthour meter in general appearance. Self-contained transformer previously used in thermal meters is eliminated: voltage component of thermal element is fed by a secondary coil wound directly over potential coil of watthour meter. This arrangement permits combining watthour and thermal demand mechanisms into a single unit. Improved design of thermal unit "greatly reduces" required operating energy, it is said. Two demand pointers are provided: one operating as a pusher; the other to indicate maximum demand. Latter cannot be shifted by vibration. Watthour mechanism has standard adjustments for full load, light load and power factor; thermal unit has only two adjustments for zero and for full scale.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*



★ Here's an unretouched photo made in pitch blackness of the new *Blackout Panel* now available with DuMont Type 208 Oscillograph.

For the first time you are offered an oscillograph with self-illuminated panel that can be *used with equal ease in darkness or full light.*

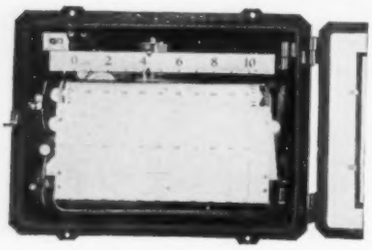
Specially-processed steel panel is treated with luminous paint that retains maximum luminosity for several minutes, and can be comfortably observed for an hour or more after that. Can be kept activated by ultra-violet light. An optional feature, the Blackout Panel is still another refinement found in this outstanding general-purpose oscillograph.

★ **Write for Literature . . .**

DUMONT
ALLEN B. DU MONT LABORATORIES, Inc.
Passaic ★ New Jersey
Cable Address: Wespexlin, New York

Temperature Controller for Throttling Fuel Heat

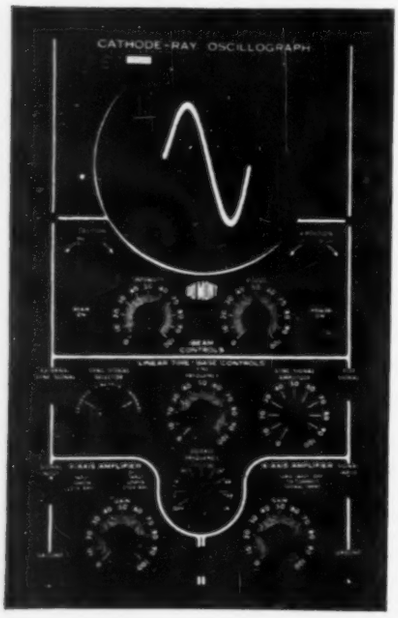
Announcement is made of new "Celectray Proportional Controller" for applications in which throttling control with or without automatic reset is required. Manufacturer



reports that the new system of control employs only a control instrument and a valve mechanism, eliminating the relay detector element formerly required. The simple method for throttling control accomplished by this instrument may be briefly described as follows: when the temperature is far below the control point as in starting up, the valve will be wide open; as the temperature rises and enters the throttling zone, the valve will close a relay. This action prevents overshooting as the temperature approaches a balance between heat input and heat loss. The throttling zone can be readily adjusted within wide limits according to the lag characteristics of the application and the maximum permissible sensitivity, easily determined in order that the load error ("droop") be kept within a few degrees on those models without reset. Other types with adjustment for manual reset (load error) or automatic reset are available. It is claimed that these instruments maintain practically "straight-line" control because of minimal "dead zone."—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Blackout-Panel Oscillograph

New "Blackout-Panel Type 20s Oscillograph" can be used under adverse lighting conditions or in total blackness when necessary. This feature may have military value. The specially processed steel panel is treated with a non-radioactive luminous paint that retains its maximum luminosity for several minutes after exposure to ordinary light, and can be comfortably observed for an hour or more after that. The glow is of



the same color and intensity as the standard medium-persistence screen of the cathode-ray tube used, thereby minimizing eye-strain. The Blackout Panel is now an optional feature with maker's Type 208 Oscillograph, a general-purpose instrument. —*Allen B. Du Mont Laboratories, Inc., 2 Main Ave., Passaic, N. J.*

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THE ONLY SINGLE BUTTON ELECTRICAL RETURN FLUXMETER
SIMPLEST AND MOST EFFICIENT
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Portable Standard with single electrical zero return.
Switchboard Type with above zero feature located on flexible lead for bench operation.
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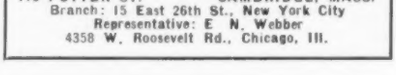

SMALL DRILLS
from .0016 up to .1969 inch diameter, all sorts of small turned parts.
Small wood screws in brass, steel, etc., turned from the bar.

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DEPENDABLE STABILITY
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Before you pass this copy of *Instruments* to the next man on the list, get him—and others—to subscribe at reduced rates under the GROUP SUBSCRIPTION PLAN.

See Page 408

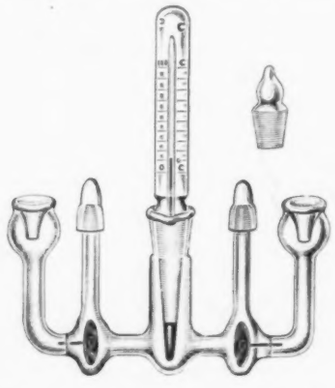
Angular Sweep for Oscilloscopes

Pictures cannot slip off the cathode-ray screen, it is said, when the 'scope is provided with new "Angular Sweep Potentiometer," a device which permits correlation of the angular position of any shaft connected

to it, and the beam position of an oscillograph. Practically any oscilloscope or oscillograph may be employed. Shaft speeds of zero to 20000 RPM are allowable and a static calibration holds perfectly even at the highest speeds, it is said. Among applications: engine indicator work (pressure vs. engine angle), engine ignition work (kilovoltage vs. engine angle), time-motion studies (time vs. angular movement), torsional vibration (time vs. delta angular displacement), motor studies (voltage or current vs. shaft angle). Standard "A.S.P." has linear characteristic (except a few degrees in 360° for return trace); special models are available with various commonly-desired angular relations. — *Rowe Radio Research Laboratory, 4201 Irving Park Blvd., Chicago, Ill.*

Fill-type Conductivity Cell

For testing electrolytes of high conductivity, new "CEL-3" fill-type conductivity cell has a constant of approx. 15, is used by placing the electrolyte in the body of



the cell proper and making connections to the conductivity bridge by means of mercury placed in the connecting bulbs on each end, with the connecting wires dipping into the mercury pools. Thermometer is supplied. Accurate positioning of the electrodes in contact with the electrolyte is assured by rigid construction. The cell is of resistance glass construction with platinum electrodes. —*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

RUBICON PORTABLE PRECISION POTENTIOMETER

Available in a number of double-range combinations, such as 1 volt and .1 volt, 100 MV and 10 MV, also in pH ranges. Guaranteed accuracy .1%. *An outstanding value.*

Described in Bulletin 270 which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

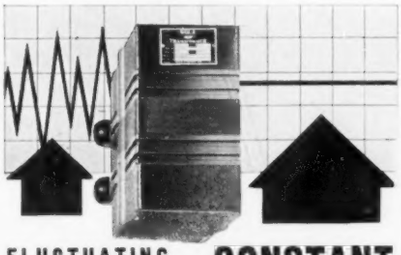
We also make galvanometers, electrometers, colorimeters, permeameters, Wheatstone and Kelvin Bridges, Resistance standards, coil testers, acronographs, clip-on transformer ammeters.

Descriptive bulletins available on request.

RUBICON COMPANY

Electrical Instrument Makers

Ridge Ave. at 35th St., Philadelphia, Pa.



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Whether it's 1 VA for an instrument or 10 KVA for a Production line—here's constant, stable voltage for you at all times, even though the line voltage varies *as much as thirty percent.*

They are fully automatic and instantaneous in operation—have no moving parts—require no maintenance—and are self-protecting against short circuit.

You can build a SOLA CONSTANT VOLTAGE TRANSFORMER into your product, or incorporate it in your production line or laboratory and know that every test will be made under identical line conditions.

Compact—economical. Standard designs are available, or units can be built to your special specifications. *Ask for* **Bulletin GCV-74**

SOLA ELECTRIC COMPANY

2525 Clybourn Ave. Chicago, Ill.

SOLA

Constant Voltage

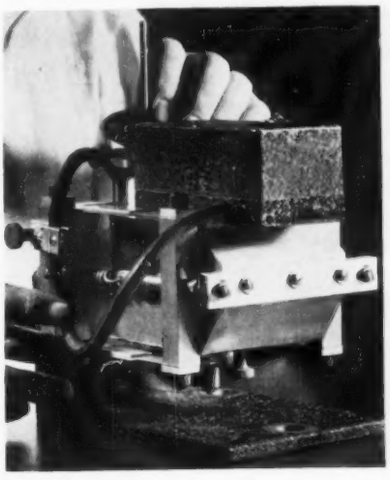
TRANSFORMERS

Temperature Compensating Capacitors

Compensating capacitors obtainable in any temperature coefficient from —0.005% to +0.005% per degree C. over a temperature range between —40°C. to +70°C. are announced. These "Type K" mica capacitors can be used to correct the normally positive temperature coefficient of inductances for the maintenance of constant *L-C* products (resonant frequency) of tuned circuits independent of temperature. They are supplied only in low-loss (yellow) XM Bakelite cases and are sealed for immersion. They are available in various capacities and voltage ratings. Specifications for individual requirements are supplied on application. An oscillator circuit using compensating capacitors will provide a constant frequency source independent of any changes in ambient temperature, or any temperature changes in the units *caused by current flow in the circuit.* Zero temperature coefficient capacitors are announced also. They are for use wherever a capacitance independent of temperature is required. One application is as a shunt for the measurement of r-f. currents with a vacuum-tube voltmeter as an indicating instrument. Among applications of the compensating capacitors are radio range beacons; also high-power oscillators where weight and space do not allow use of quartz crystal oscillators and associated apparatus (oscillator frequency stability said to be comparable to that obtained with quartz crystals). —*Aerovox Corp., New Bedford, Mass.*

Equipment for Balancing Machines on Own Pedestals

Low-speed machines, such as waterwheels and Disel-driven generators rotating at as low as 100 r.p.m. (previous low limit 600) may now be dynamically balanced on their own pedestals. This has been made



possible by means of a new pick-up which indicates vibrations of double amplitude as low as 0.003" at 100 r.p.m. and is used with a standard portable balancing unit and conventional sine-wave generator. New pick-up employs something like an inverted pendulum. The frequency of an ordinary pendulum, operated by gravity, can be lowered by lengthening its arm—the way a grandfather's clock is regulated. Similarly, the natural frequency of an inverted pendulum can be made extremely low by weakening the restoring springs so that it is barely stable in a vertical position. To permit the use of this pickup in all directions, the effect of gravity has been eliminated by laying the pendulum on its side, and the force previously supplied by gravity is furnished by a toggle-like spring mechanism attached to the pendulum.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

"DUCTER" Low Resistance OHMMETER

a Direct-Reading field Instrument

—down to .000001 ohm

Built to "stand the gaff" of field use, this direct-reading pointer-type instrument can be used to measure contact and conductor resistances out on the system as well as in shop or laboratory. It is proving an invaluable tool for maintaining circuit breakers, checking switch and relay contact resistances and in testing armature, field and transformer coils.

The Ducter Ohmmeter is designed and constructed to "Megger" standards of ruggedness and reliability. It operates from a storage battery, and by applying testing leads one can actually see at a glance the condition of vital parts of electrical equipment, namely, contact resistances.

Write for illustrated descriptive Bulletin 1635-I.

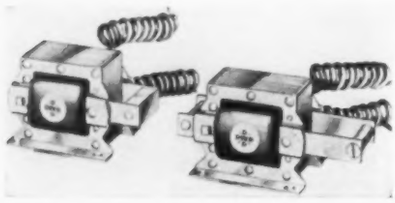
JAMES G. BIDDLE CO.

Electrical Instruments

1211-13 ARCH ST., PHILADELPHIA, PA.

Solenoid for Operation and Control

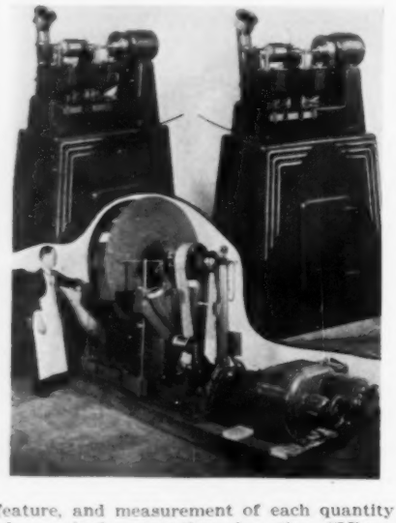
New laminated type solenoid is said to meet the demand for rugged construction and positive reliability in control of production machinery, operation of hydraulic



valves and other industrial applications. It is for constant or intermittent duty on a.c. and is furnished with either push or pull type plungers as illustrated. Field coil is paper section wound, taped and treated to be impervious to cutting oils. It measures 2″ × 2″ with a plunger stroke of ¾″; can be had for any voltage; has a minimum push or pull of 5.5 lbs. at full line voltage, and 3.75 lbs. at 85% of line voltage.—*Dean W. Davis & Co., Inc., 549 W. Fulton St., Chicago, Ill.*

Balancing Machines

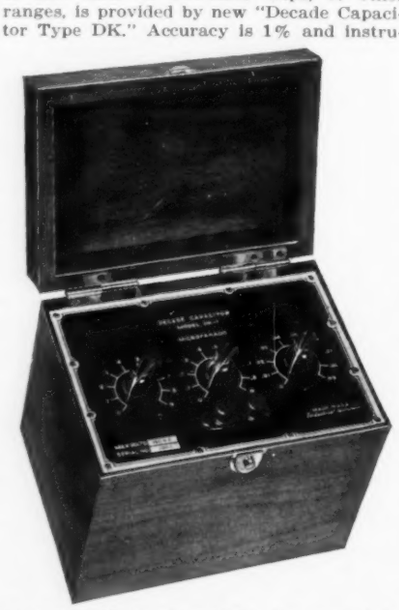
Three new types of balancing machines are announced. Upper part of illustration shows two "Special Super-Sensitive Dynamic Balancing Machines" used in a production line to analyze static and dynamic balance in automobile generator armatures. By a simple adjustment, machines may read either pure static unbalance or dynamic unbalance. Upper dial records angle of unbalance in each end of the armature. Smaller dials on each supporting head record amount of unbalance either in ounce-inches or fractions of an ounce as desired. These readings are made automatically at the time of recording the angle of unbalance. Lower part of illustration shows new "Model NE-90 Super-Sensitive Dynamic Balancing Machine" which has a commercial range of 200 to 10,000 lbs. Application illustrated is for fan balancing, for which these machines are desirable by reason of rugged design, mechanical separation of correction planes by means of the "Equipoise"



feature, and measurement of each quantity of required correction by the "Micro-Indicators." Not illustrated is the new "NE-48 Super-Sensitive Dynamic Balancing Machine" for determining the amount and location of the correction weights required in overcoming the dynamic unbalance in rotating parts weighing from 50 to 1500 lbs. Amount of required correction for each correction plane is recorded on the "Micro-Indicator" dials which are sensitive to 0.2 ounce-inch of unbalance. Angular location of the required correction for each correction plane is recorded by the "Neon-Lite" indicating system. It is said that the average operator is able to determine the required corrections for an average rotor in less than half a minute on these machines. The shaft on the part to be balanced is supported by two self-aligning ball bearings in each saddle which are radially adjustable to accommodate shaft sizes from 1½″ to 3¾″. Additional sizes can be accommodated up to 6″ by means of extra saddle adapters. It is said that a minimum set-up time is provided by the quick-change features. Since parts to be balanced on these machines may run at varying speeds, a wide variety of speed-ranges is provided in this particular machine by driving the balancing spindle through V-belt and a standard commercial vari-drive.—*The Globe Tool & Engineering Co., 418 Davis Ave., Dayton, Ohio.*

Decade Capacitor

A choice of any capacity value from 0.01 to 11.1 mfd. in 0.01-mfd. steps, or other ranges, is provided by new "Decade Capacitor Type DK." Accuracy is 1% and instru-



ment is said to be suitable for most laboratory as well as industrial applications, particularly for bridge measurements, filter design and experimental tuned circuits. Panel has three knobs and dials calibrated directly in capacitance so that reading from left to right totals up the value available at the binding posts. All decades employ paper or mica dielectric capacitors "of highest quality and stability." Instrument measures 7″ × 8″ × 5¾″ and weighs 8 lbs. Three models are available: 11.1 total in 0.01 mfd. steps; 1.11 mfd. in 0.001 steps; and 1.11 in 0.001 steps with mica dielectric throughout. —*Industrial Instruments Inc., 156 Culver Ave., Jersey City, N. J.*

Electronic Photofluorometer

New "Model 12 Electronic Photofluorometer" was designed in collaboration with nationally known authorities in the milling industry and in the field of bio-chemistry. Emphasis has been laid upon easy operation and accuracy. Instrument uses a high vacuum phototube coupled with an electronic amplifier to secure fast readings on a deflecting-pointer indicator, therefore is non-sensitive to vibration and rough handling. The ¾″ test tube type cuvettes are cheap, easy to handle and clean, and permit readings to be made with as little as 8 ml of solution. It is unnecessary to pipette an exact amount of liquid into the cuvette. The filters used are said to be of the most specific type and follow recognized standard procedures. It is said that the high sensitivity of the phototube and electronic amplifier makes it unnecessary to sacrifice either specificity or low blank readings by the use of thin high-transmission filters, yet the sensitivity is, in general, several times as great as has been previously found practical with non-electronic devices using sensitive galvanometers. Instrument incorporates a shutter which exposes the solution to the illumination only during the actual test, thereby eliminating error which might be caused by bleaching of the unstable fluorescent solution. Electrical blank compensation, also incorporated, facilitates testing a large number of like samples by eliminating the calculation of the blank correction. *Principles of operation:* A high-intensity mercury arc lamp rated at 100 watts throws illumination through an aperture which is closed by a push-button operated shutter except while readings are being made. A specific filter then isolates a single wavelength, 365 for B_1 or 436 for B_2, for illumination of the cuvette containing the sample. The fluorescence generated in the sample passes through another filter which blocks off the exciting wavelength. Only the fluorescent wavelength illuminates the cathode of the phototube. Phototube output, after amplification by linear vacuum tube amplifier, is read from the scale of a large, rugged, pointer type indicator. All adjustments are made by three simple controls. One of these, used only occasionally, adjusts amplifier to proper operating conditions. The second adjusts range of instrument to give desired reading for standard. The third, or blank adjustment, is zero setting which may be used to cancel out a blank reading. Operation consists in slipping a test tube containing a stable solution, such as quinine solution, into the hole in the panel, checking zero adjustment, pressing shutter button and adjusting indicator to, say, 100. Sample to be measured is then substituted for the standard and the shutter is pressed: new reading is proportional to concentration of sample. This may take less than 30 sec.—*Coleman Electric Co., Inc., Maywood, Ill.*

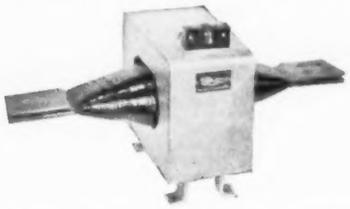
Two-speed Fan Control

Switching system of new furnace fan control, for forced warm air systems employing two-speed fans, is designed to start the fan on temperature rise and only on low

speed, in order to protect fan motor. Control can be set to switch the fan from low to high speeds at any desired bonnet temperature. All cut-in and cut-out settings are made independently. Bonnet temperature is indicated on an external scale. Turning external knob to "Summer Cooling" position produces continuous high-speed fan operation without disturbing temperature settings.—*Perfex Corporation, Milwaukee, Wis.*

Current Transformer

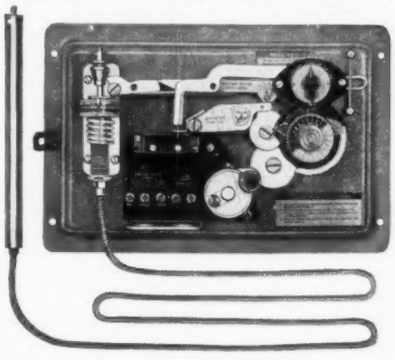
For high-speed bus-differential protection, new "Type JD" transformer embodies an air-gap core design which permits maintaining linear relation between primary and



secondary currents even where completely offset high-current values are encountered. New transformers are designed to operate at currents as high as 100,000 amp. with a constant ratio up to the designed value. A-c. accuracy is not affected by the d-c. component of the short-circuit current and does not produce any appreciable d-c. component in its secondary. Core punchings are rounded and stepped back at gaps to prevent concentration of flux at edges. Several gaps are employed instead of one; they are symmetrically disposed in the core to minimize interference effects as well as to reduce the fringing of flux that would occur with one large gap—*General Electric Co., Schenectady, N. Y.*

Three-element System for Heating Control

New "Model 7 Tri-trol Regulator" controls heating in accordance with outside temperature and programs heating according to the hours of activity and outside temperature. It is said to offer all the vari-



ous controls and switches necessary for completely automatic heat regulation based on outside temperature. Manufacturer emphasizes that its low cost justifies its profitable use not only in larger buildings, but in smaller buildings down to two-family apartments. By controlling heating from the outside, it is said to act as a preventive, rather than a corrective, regulator. It responds to any change in weather before building temperature is affected, and as a result is said to eliminate completely over- or under-shooting. Its automatic operation guards against late starts on cold mornings, or premature, fuel-wasting starts on warm mornings. Among built-in features: a "refueler" or hold-fire switch, an automatic cut-off when outside temperature rises above 65°, and a special four-position switch which provides added flexibility for those buildings which require varied heating programs. Adjustments adapt it to all conditions, in any kind of building, in any location, with any automatic firing. It is said to take the place of a return line aquastat, day-night switch, hold-fire timer, 65° cut-off, relay (for jobs up to ½ Hp.) and other accessories necessary for completely automatic heat control.—*Marsh Tritrol Company, 600 S. Michigan Ave., Chicago, Ill.*

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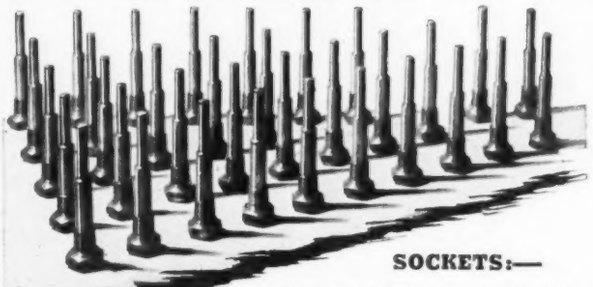

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Instrument Requirements for High-frequency Power Applications

By L. J. LUNAS
Engineering Dep't, Westinghouse Electric & Mfg. Co., Newark, N. J.

RECENT applications of high-frequency power to electric furnaces has involved a necessity for electrical instruments to read current, voltage power, reactive power (vars.) and power factor. Frequencies have steadily increased, starting with 480 cycles, and progressively going to 960, 1920, 2400, 4800, 9600 cycles, until the most recent installation of 11,520 cycles.

Induction furnaces must be operated at near-unity power factor for best efficiency and to prevent overheating generator equipment. Since the permeability and conductivity of the charge varies with temperature, it is necessary to know power factor and other load conditions making necessary adjustments for best operation. In the case of short-time heating cycles, such as heat treatment and hardening operations which last only a few seconds, the degree and depth of hardness are controlled by operating at the proper current and power factor for the right time. These values are predetermined by the use of instruments and successive production is duplicated with best results controlling performance as indicated by instruments.

Instruments for this application must have high overload capacity, quick response, and other characteristics usually found in industrial power instruments. These qualifications preclude the use of thermal instruments, such as used for radio-frequency circuits. Conventional instruments as designed for power frequencies may be used only up to a few hundred cycles with any reasonable degree of accuracy. It therefore is necessary to make modifications in the design, as well as to calibrate and make adjustments at the operative frequencies. This development also made it necessary to provide suitable sources of frequency and high-frequency calibration standards.

TYPES OF INSTRUMENTS

1. Ammeters

Ammeters of the moving iron-vane type were found to be more suitable than electrodynamic or electrothermic instruments for audio-frequency work. The mechanism is more rugged with higher overload capacity, and the scale of the repulsion iron vane ammeter is more uniform so that better accuracy of readings is obtained, especially at light loads. The frequency error of such an instrument is shown in the curve Fig. 1. At the higher audio frequencies, the eddy current losses in the mechanism's metal parts cause excessive temperature rise, making it necessary to fabricate these details of special high-resistance alloy materials and to laminate the iron vanes.

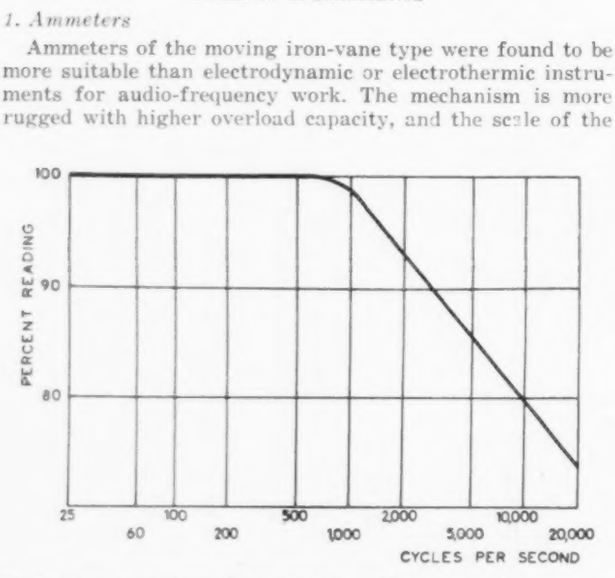


Fig. 1. Frequency response characteristic of repulsion moving iron ammeter.

2. Voltmeters

Electrodynamic and moving-iron type voltmeters are limited to frequencies of a few hundred or, at most, a few thousand cycles per second, due to the relatively high ratio of inductance to resistance. Electrothermal voltmeters have low overload capacity, which makes them undesirable on induction heating circuits having poor regulation. Therefore, the most practical type of voltmeter for higher audio frequencies is the rectifier type. Since rectifier instruments measure the average value and must be calibrated on a sine wave with the scale marked in r.m.s. values, wave-form errors must be eliminated. This is accomplished by the use of a suitable filter network. This is particularly important in induction-heating applications, since the wave form varies with load conditions. Rectifier units have been developed to the point that frequency errors in the audio range and temperature errors have been reduced to commercially allowable limits.

3. Wattmeters

The chief source of error in electrodynamic wattmeters in the audio-frequency range (above approx. 150 cycles) is the inductance of the voltage circuit. At power frequencies the voltage circuit current is practically in phase with the voltage applied. The angle of lag may be from 10 to 20 minutes. However, at higher audio frequencies this phase angle becomes great; for example, at 9600 cycles the angle of lag is around 40 degrees. This would cause the wattmeter to read about 25 percent low. It therefore is necessary to provide compensation for this frequency error. This is accomplished in a simple manner by connecting a capaciter of suitable value in parallel with the non-inductive resistor of the voltage circuit. The mathematical theory of this compensation scheme need not be discussed here; suffice it to say that the method is satisfactory.

4. Varmeters

A wattmeter compensated for frequency and provided with a phase-shifting network to turn the voltage circuit vector 90 degrees in a lagging direction will indicate the reactive power or vars. This instrument will read zero at unity power factor and full scale at zero power factor. Varmeters are usually furnished with a zero center scale to provide indications for both lagging and leading reactive power.

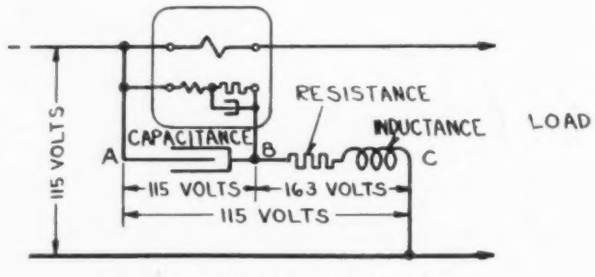


Fig. 2. Phase shifting network for varmeter.

The phase-shifting network consists of a circuit having capacitance, inductance and resistance as shown in Fig. 2. The vector diagram is shown in Fig. 3.

5. Power Factor Meters

Power-factor meters for audio-frequency work are similar to cross-coil electrodynamic instruments used for power frequencies except that it is more practical to use a capacitance instead of an inductance in the resister-reactor

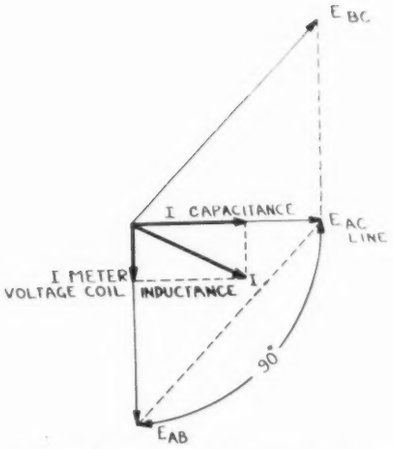


Fig. 3. Vector diagram—phase-shifting network for varmeter.

network used for developing the rotating field in the moving-coil voltage circuit. The schematic diagram of the instrument in the circuit is shown in Fig. 4.

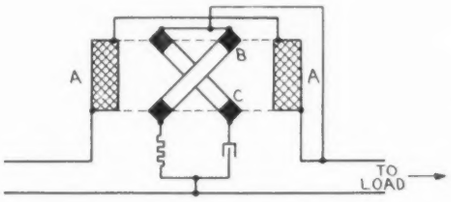


Fig. 4. Schematic diagram—power-factor meter.

CALIBRATION

Calibration of instruments for audio-frequency applications requires adjustable-frequency power sources and suitable calibration standards. In the case of power factor meters it is necessary to have sources for both current and voltage, with means for varying the phase angle between them.

Ammeters are calibrated in series with a thermocouple type instrument as a standard, connected to the oscillator set for the desired frequency. Sinusoidal wave form is maintained by selecting a tap for proper impedance. A cathode-ray oscilloscope is used for checking wave form.

Voltmeters are calibrated in a similar manner, using a thermocouple voltmeter connected in parallel as a standard.

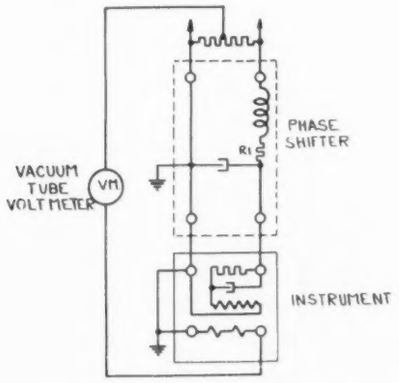


Fig. 5. Calibration circuit for varmeter.

Wattmeters are calibrated in the conventional manner on a 60-cycle source. Frequency compensation is adjusted by passing a current of about 12,000 cycles through the current coil and short-circuiting the voltage-circuit terminals. Any motion of the moving element when the voltage terminals are short-circuited indicates the necessity of compensation. When the capacitance is connected across the proper portion of the resister of the voltage circuit, no deflection results from the short circuit, and the instrument is practically free of frequency error over the complete frequency range to 12,000 cycles.

Varmeters, being similar to wattmeters, have the instrument proper calibrated and adjusted in the same manner. The phase-shifting network is calibrated for 90 degrees lagging by adjusting the value of the inductance and resistance. The calibration circuit is shown in Fig. 5. Since the current in the instrument voltage circuit must be 90 degrees out of phase with the line voltage, the adjustment in the phase-shifting network must be made to produce this shift which gives zero deflection on the vacuum-tube voltmeter. The magnitude of the voltage output of the network is made equal to the input or line voltage by adjusting resistance $R1$.

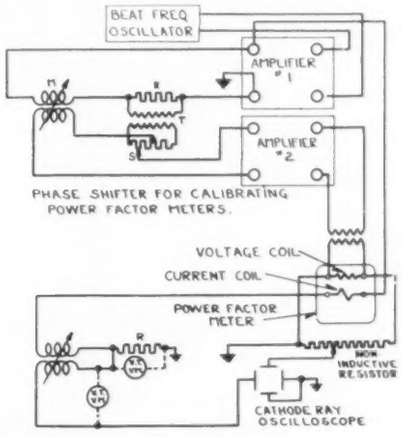


Fig. 6. Circuit diagram for calibrating power-factor meters at audio frequencies.

Power-factor meters are calibrated with the circuit arrangement shown in Fig. 6. The voltage applied to the voltage circuit of the instrument under test is applied to one set of plates of a cathode-ray oscilloscope, while a voltage in phase with the current in the current circuit is applied to the other set of plates. The amplifiers in the cathode-ray oscilloscope must have no phase shift. This can be checked by applying the same voltage to both sets of plates and noting the image.

The phase angle between the two voltages applied to the oscilloscope can be determined by measuring the axes of the elliptical image in the screen, but precise measurements are not possible as it is difficult to read exact deflection values. A more accurate method of determining the phase angle is to bring the two voltages exactly in phase, which produces a precise, easily determined, straight-line image on the screen. By using vacuum-tube voltmeters, it is then possible to measure the voltage in phase with the noninductive resistance R, which is in phase with the current in the current circuit of the power factor meter, and to measure the voltage across the mutual inductance, which is 90 degrees leading the current in the current circuit of power-factor meter. In bringing the image on the oscilloscope to a straight line, this latter voltage (the out-of-phase component) is adjusted in magnitude so that the vector sum of the two voltages is brought in phase with the voltage across the voltage coil of the power-factor meter. The ratio of the two voltmeter readings is therefore a measure of the tangent of the phase angle, from which the phase angle and power factor can be calculated accurately.

MEASUREMENTS FOR INDUCTION-FURNACE CIRCUITS

Operation of induction furnaces or any high-frequency heating load requires accurate reactive measurements for two reasons.

(1) Power factor of the load is relatively low; about 10 percent in the case of an induction furnace. Since a generator cannot be made for, say, 100 kw. of load and 900

(Continued on page 408)

Maintenance and Servicing of Electrical Instruments

By JAMES SPENCER

Foreman, Instrument and Relay Testing, Westinghouse Elec. & Mfg. Co., Newark, N. J.

CHAPTER III
A-C. WATTMETERS

Wattmeters are instruments used for measuring directly the power or watts in an electric circuit. Wattmeters are made in switchboard and portable types for both indicating and recording use. For the present we shall cover only the switchboard indicating type. Portable and recording types will be taken up later.

To clarify the actions and functions of the wattmeter, it might be well to review the subject of power as related to both a-c. and d-c. circuits. In direct-current circuits we found that the power in any circuit is the product of the

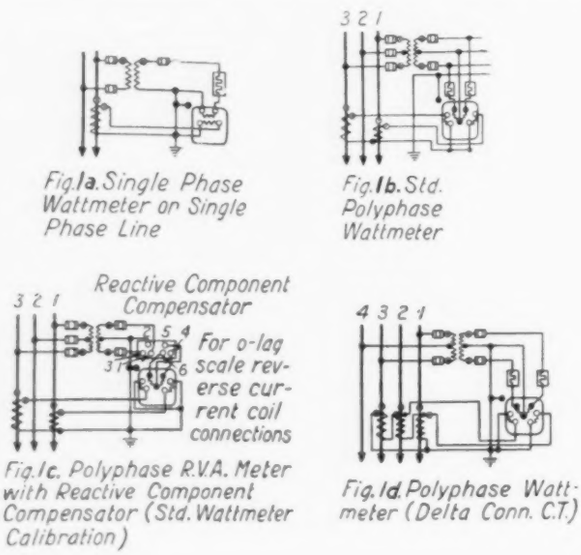


Fig. 1a. Single Phase Wattmeter or Single Phase Line

Fig. 1b. Std. Polyphase Wattmeter

Fig. 1c. Polyphase R.V.A. Meter with Reactive Component Compensator (Std. Wattmeter Calibration)

Fig. 1d. Polyphase Wattmeter (Delta Conn. C.T.)

Fig. 1e. 2 Ph. 4 Wire Polyphase Wattmeter

Fig. 1f. 3 C.C Wattmeter

Fig. 1. The six commonest a-c. wattmeter connections. They should be learned by heart.

current in amperes and the voltage of that circuit or $P = E\,I$. In alternating-current circuits, however, there is a different situation to contend with, as there is another variable to be considered, namely power factor. As the term power factor and the power factor meter are discussed elsewhere in this book we shall pass by merely saying that the power factor is the term by which the volt-amperes of a circuit is multiplied to give the true power of the circuit. The power of a single-phase alternating current circuit is expressed as, $P = E\,I \cos \theta$ where the cosine of the angle of lag or lead of the current to the voltage, is the power factor of the circuit.

In a-c. systems the most common circuits are single-, two-, and three-phase circuits, the power of each circuit being found as follows:

A Contribution to National Defense

IN normal times it is inadvisable for users of electrical instruments (except users such as utilities with fully-equipped service laboratories) to do any work which involves opening up the case. Before 1941, the only articles on adjusting and servicing instruments which we accepted for publication were on Bourdon gages and other comparatively rugged measurement and control devices. And all we published on the subject of repairs and rebuilding was our stock editorial (reprinted every two or three years) saying "Let the factory do it."

But this national emergency has created a shortage of electrical instruments, so that even plants enjoying priority have to wait. The top shelves of stockrooms are being searched for old instruments. "Irreparable" instruments are being "repaired." And —perhaps most important—all instruments in use must be maintained in good condition . . . by the users. Hence the crying need for this serial—the first and only one of its kind.

NOTICE TO STUDENTS IN INDUSTRY

The conclusion of Chapter II, dealing with a-c. voltmeters, will be published later. Yes, it *looks* like a balled-up schedule.

But it's for your convenience, fellows: many of you couldn't wait too long for Jim Spencer's chapter on a-c. wattmeters. Now, then, the first part of Chapter II (dealing with a-c. ammeters, etc., but not voltmeters) appeared in our September issue. Our October and November issues were "specials" and did not include instalments of Spencer's book. If we *had* to follow a schedule (for example if this book were a "who-dun-it" serial) we wouldn't comply with the requests of eager readers who asked us to omit the middle and print the ending shortly after the beginning. But in this case it's different: the conclusion of Chapter II, though not unimportant, will "keep"—and meanwhile here's a lot of the most important practical dope on a-c. instruments ever published.

By the way, although we are arranging this SERIAL for utmost convenience of Defense workers, we shall re-arrange the BOOK so that the sequence of Jim Spencer's topics will make a first-class text for students as well as for men actually doing repair work.

$1\,\phi$ power $= E\,I \cos \theta$ or $E\,I$ (P. F.) or $\left(I^2 R \text{ or } \frac{E^2}{R}\right)$

$2\,\phi$ power $= 2\,E\,I$ (P. F.) balanced circuit

$3\,\phi$ power $= \sqrt{3}\,E\,I$ (P. F.) balanced circuit

Ammeters & Voltmeters in one phase only

From the above we find:

$$\text{P. F.} = \frac{\text{Watts}}{\text{Volts} \times \text{Amps}} \text{ for } 1\,\phi$$

$$\text{P. F.} = \frac{\text{Watts}}{2 \times \text{Volts} \times \text{Amps}} \text{ for } 2\,\phi \text{ balanced circuit.}$$

$$\text{P. F.} = \frac{\text{Watts}}{\sqrt{3} \times \text{Volts} \times \text{Amps}} \text{ for } 3\,\phi \text{ balanced circuit.}$$

Wattmeters may also be used to measure reactive kilovolt-amperes or kilovars with the addition of an external reactor connected as an open delta transformer, as shown and explained later.

Connections:

Since the line connections of wattmeters are so varied due to the different types such as single-phase, polyphase, three current coil, etc., an explanation of connections can best be given by diagrams as in Fig. 1.

Electrodynamic Type

Construction:

The polyphase wattmeter of the electrodynamic type is essentially two single-phase wattmeters, mounted so that the pointer shaft that carries the moving coils is common to both elements. As both the polyphase and single-phase meters are similar the single-phase meter only will be described.

A typical single-phase wattmeter assembly as shown in Fig. 2 consists of a base and cover of pressed steel, that not only serves as a base mounting for the element but also as a magnetic shield. The pressed steel construction of the base and cover is best because as they are pressed into form

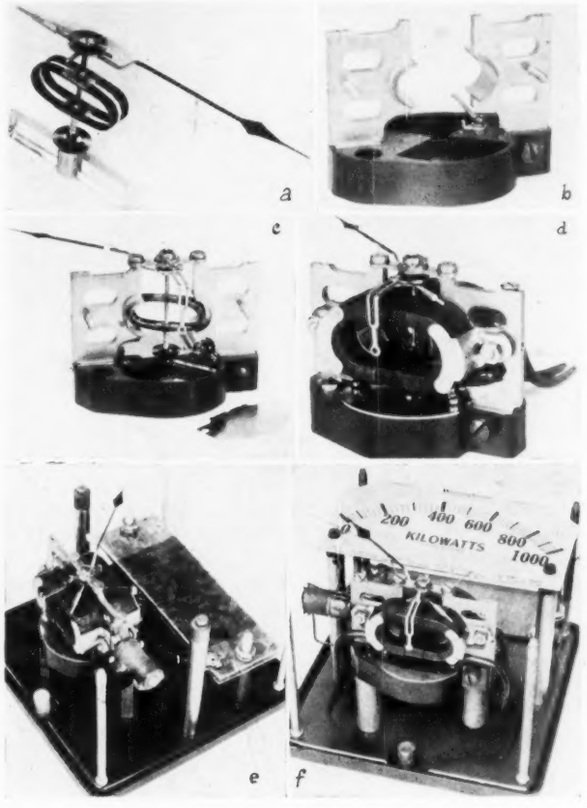


Fig. 2

(a) Moving element assembly of a single-phase wattmeter.
(b) Sub-base with supporting brackets and damping chamber open.
(c) Single-phase moving element assembled in sub-base.
(d) Complete mechanism of a single-phase wattmeter.
(e) Single-phase wattmeter with cover and dial removed.
(f) Single-phase electrodynamometer wattmeter, with cover removed, showing internal construction.

the metal cross-section is uniform throughout and the tendency of warping is reduced to a minimum. The full glass front of the cover, the dust-proof gaskets, the molded terminal blocks and the brass mounting bolts complete the base.

The metal element frame is mounted in a molded sub-base (Fig. 2b) that holds the lower jewel and forms the damping chamber. Two brass cover plates (Fig. 2c) are used to close the damping chamber. The upper bridge between the two sides of the element frame is a mounting for the upper jewel, an anchor for the upper spring and a mounting for the zero adjustor. The lower spring is mounted on a bracket attached to the sub-base. The dial mounted on the element frame at two points (see Fig. 2e) serves as the nameplate, as well as having a 100° scale that is easily read from almost any angle.

A close inspection of the moving element in Fig. 2c will reveal that one end of the coil is connected to the upper spring and the other end to the lower spring. As the upper spring is grounded to the element shaft and the frame, it is not necessary to insulate the pigtail connected to this spring. The lower spring, however, is insulated from these metal parts and therefore the lower connection of the coil must also be completely short-circuited. To attain this condition, the lower part of the element shaft is covered with insulating paper before winding the pigtail around the shaft to get to the connecting point of the spring.

The copper-wound stationary coils are positioned on the frame over guide brackets attached to the frame and are held in place by clamps, bolted to the frame as shown in Fig. 2d.

The main shaft, besides carrying the pointer with its system of balance arms and weights, carries also a single moving coil, or one moving coil for each element if polyphase (as shown in Fig. 3), the phosphor bronze conducting springs and the aluminum damping vane. The shaft is pivoted at both ends with hard steel pivots.

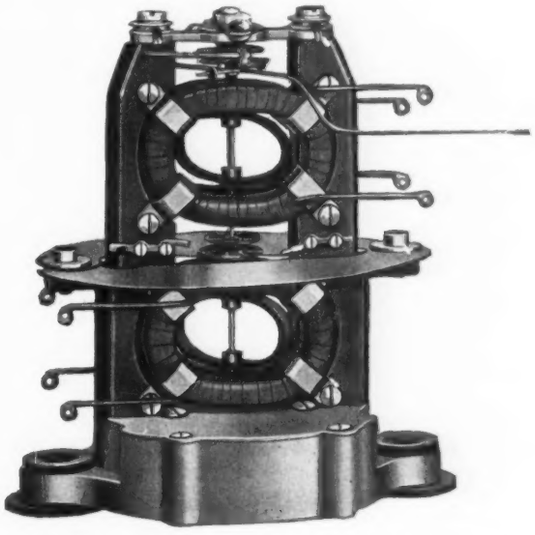


Fig. 3. Measuring element of an electrodynamic polyphase wattmeter (Roller-Smith Co.).

A calibrating resistance is connected in series with the voltage coil internally and each meter element takes an external resistor. The external resistor is usually of the clay spool, iron base, wire screen side type, the external connections being made through terminals mounted in Moldarta (or other such material) and projecting through the iron base.

Principle of Operation:

A review of the principle of attraction and repulsion of parallel wires carrying current (see Chapter II) will greatly help to understand the principle of operation of the electrodynamic wattmeter.

Up to now, we have spoken of power measurements of d-c. circuits as the product of the current and voltage of the line. Under these conditions we have measured power with a voltmeter and ammeter.

In a-c. circuits the power or watts is equal to the product of the effective current and voltage at unity power factor only, therefore, it becomes necessary to have a wattmeter for this purpose as the voltmeter-ammeter method can seldom be used.

The electrodynamic type wattmeter as explained below is one of the most widely used types of wattmeters.

Fig. 4 shows the correct way the electrodynamic type wattmeter should be connected to the line so that the current and the voltage coils are connected at zero and therefore at the same potential. A-A_1 are the current coils, B is the voltage coil and C is the series resistance used in the voltage circuit. The current coils are connected in series with the line and are wound with sufficiently heavy wire to carry the load current.

Although the moving coils and stationary coils of the wattmeter are not electrically connected as in the ammeter and voltmeter of this type, the principle of operation is the same. The stationary coils of the wattmeters are current-carrying while the moving coil is connected across the voltage circuit. From the above we may then say that the action of the wattmeter is dependent upon the interaction of the flux of the current coil and voltage coil. To better understand the above let us say that when a current flows

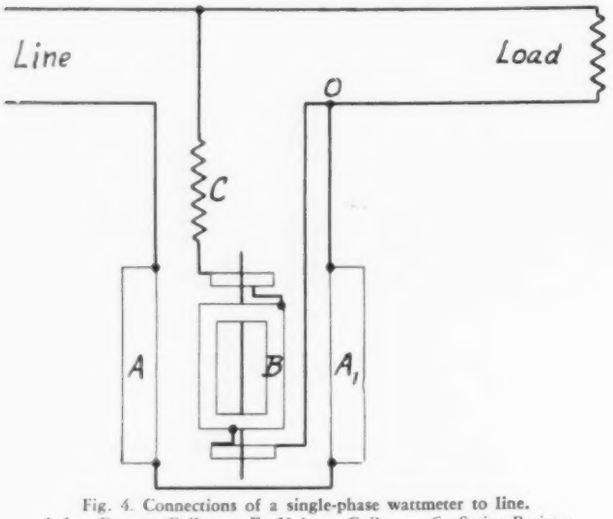


Fig. 4. Connections of a single-phase wattmeter to line.
A-A_1—Current Coils *B*—Voltage Coils *C*—Series Resistor

in the potential and current coils, magnetic fields are established that tend to oppose one another. As the voltage coil is pivoted and free to move, it is repelled to a point where the torque due to the electrical forces balances that of the mechanical force or spring that retards the action of the moving system.

Since there is no iron used in the mechanism of this type of instrument, the field due to the current of the current coil is proportional to the current of the coil at all times. Likewise the current in the voltage coil is proportional to

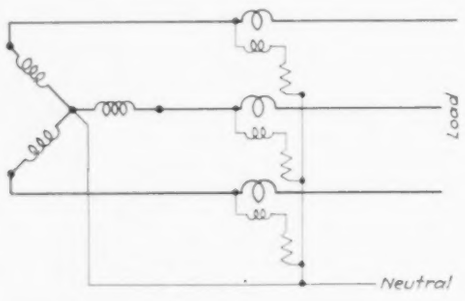


Fig. 5. Three-wattmeter method of power measurement. (From "Industrial Electrical Measurements and Control" by Borden and Behar.)

the voltage at all times. Thus the torque is proportional to the product of the instantaneous current and voltage of the system.

The electrodynamic type instrument measures the power of a system accurately, regardless of the system power factor. This is explained in that the electrodynamic type meter measures average power. If the power factor drops below unity, there would be a negative torque for a part of a cycle and the torque of the series coil and that of the potential coil would oppose each other and the moving coil takes a position of average torque. As explained later under "tests," the position of the moving coil affects the torque of the instrument and is evidenced by a change of scale distribution.

In the three-phase wattmeter we have two single-phase elements connected together in such a way that the instrument gives a reading corresponding to the algebraic sum of power in the system. Power of a three-phase line can be measured with three single phase wattmeters connected as in Fig. 5, or with two single phase wattmeters as connected

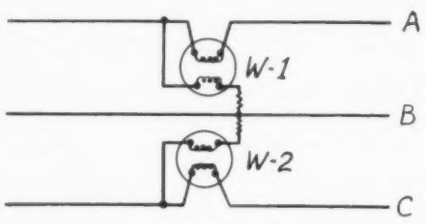


Fig. 6

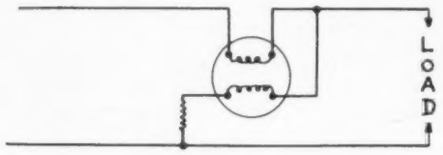


Fig. 7

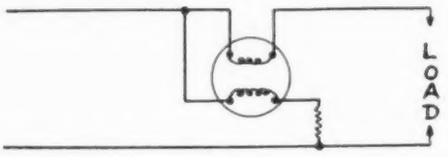


Fig. 8

in Fig. 6, and calculated as $WA \pm WB =$ total power. If the system is below 50% P.F. we use the minus sign; and when above, the plus sign. From this we can see that the true power of a three-phase circuit above 50% power factor is the sum of the two wattmeter readings. At 50% power factor, it will be found that one wattmeter will indicate zero while the other will indicate the total power in the

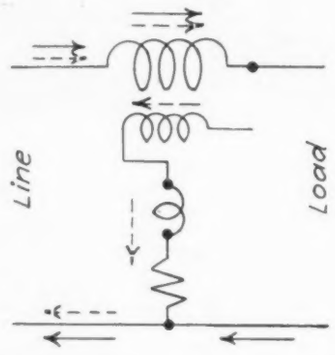
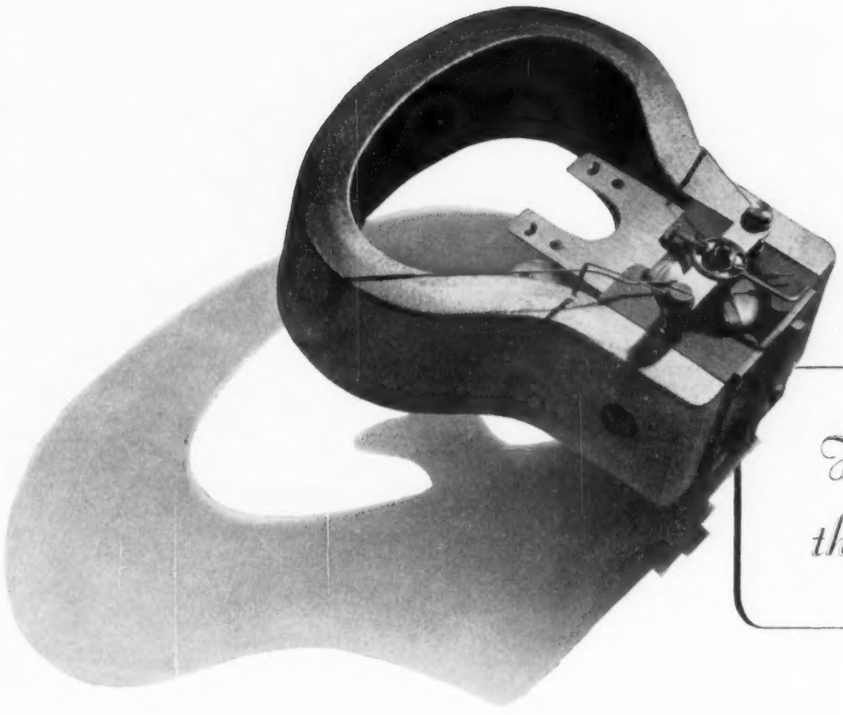


Fig. 9. Losses in the wattmeter. Full arrows indicate flow of load current; dotted arrows indicate flow of voltage coil current. Voltage circuit loss compensated out. (From "Industrial Electrical Measurements and Control" by Borden and Behar.)

circuit. When the power factor is below 50%, one of the wattmeters will read reverse. To correct this condition, so that both wattmeters will read forward, interchange the current leads on the wattmeter reading reverse. The total power of the circuit can then be found by subtracting the smaller indicated value from the larger. The current coils are reversed rather than the potential leads, in order to keep the current and potential coils at zero or at the same potential.

When connecting a wattmeter in a line there are two methods, one where the wattmeter measures the current taken by the voltage coil, Fig. 7, and the other where it measures the voltage across the current coils as in Figs. 8 and 9.



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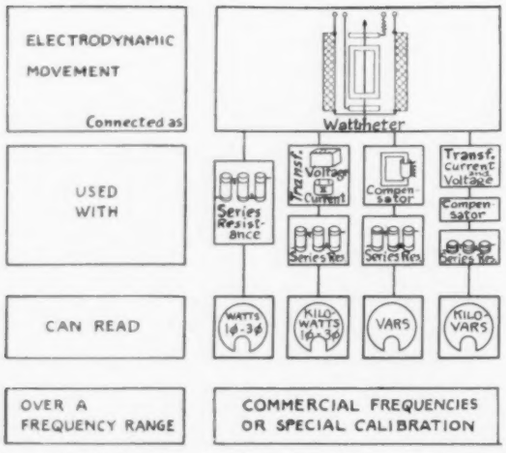

Fig. 10. Application chart for electrodynamic type a-c. wattmeter.

For further information on the application of electrodynamic type instruments, and the auxiliary equipment used with this type, see the chart, Fig. 10.

Test and Calibration:

When mechanically inspecting a wattmeter, the instrument should first be carefully inspected, to see that it is clean and well polished and that no foreign material is lodged inside.

Current and voltage terminal connections should be tight. Check to see that all nuts, screws and solder connections are well made. See that convolutions of the spring do not touch and that springs and other parts are not corroded. Spring adjustor should be at right angles to bridge to allow for resetting zero when slight changes take place.

Bumpers on dial should be checked for proper alignment so that pointer will pass zero and full-scale.

See that moving element has proper end play and that there is no friction in a vertical or horizontal position. Jewel, lock nut and dial screws should be tight and balance should be good in all positions as in Figs. 5, 6 and 7 of Chapter I.

Ground test the instrument at not less than 1500 volts from all current and voltage terminals to base, also 1500 volts between current and voltage terminals as per A.S.A.-1938 specifications.*

The electrical test and calibration adjustments of wattmeters, whether they be single-phase or polyphase, follow somewhat the same method of adjustment except that in the polyphase the front and rear elements are balanced against each other. In practice, the polyphase wattmeter is usually calibrated on a single-phase line and checked for polarity on a three-phase circuit. As a means of simplifying the explanation of testing these instruments we shall outline the single-phase wattmeter test, after which the variations and additional operations required for the polyphase test will be given.

If an instrument is to give long and satisfactory service, its mechanical assembly and adjustments should be made properly. A mechanical check to ascertain that soldered connections, end play, balance, springs, clearance of moving parts, etc. are correct, should be made before connecting the instrument to the test circuit.

With the instrument connected as shown in Fig. 11, current and voltage should be applied to check polarity. If the pointer is deflected up scale, the connections are correct. If the pointer tends to indicate below zero, the connections are incorrect and can be made right by reversing the current or voltage leads. With the instrument indicating in the right direction, and connected to the circuit with a suitable standard, the full-scale adjustment may be made. This adjustment may be made by changing the resistance in series with the voltage element or by changing the strength of the control spring. In some cases it is convenient to remove wire from the resistor, but where resistor units are used having a baked finish, the varnish should be removed with a hot iron and turns of wire shorted with solder. Spring adjustments are made as outlined under "ammeters" in Chapters I and II.

Wattmeters are designed, assembled and tested to have a fairly even scale distribution. That is, the first and last main divisions of the scale should be equal. If they differ noticeably, the moving coil has probably shifted and should be corrected and made tight on the shaft by whatever mechanical means is available or by the use of a good household cement. In correcting a change of scale distribution, it is necessary to readjust full scale with each change of coil position. To simplify this operation, a variable resistor such as a decade box can be used in place of the regular resistor to make corrections, after which the permanent resistance of the instrument should be adjusted.

With the foregoing operations completed, the balance should again be checked and adjusted if necessary, after which the instrument should be calibrated by comparison with a standard of known accuracy.

Polyphase wattmeters may also be tested on a single-phase circuit; in fact this is the method used by most instrument manufacturers. The polarity test of a polyphase wattmeter, however, is best made on a polyphase circuit where the phase sequence is definitely known. Each element

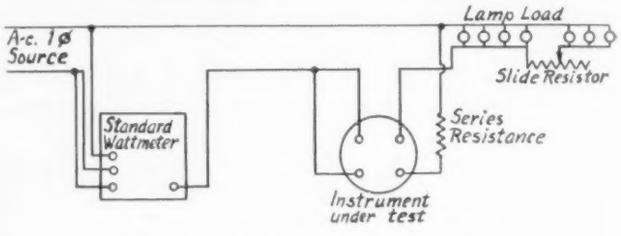

Fig. 11. Test circuit for single-phase wattmeter.

of the polyphase wattmeter is first tested separately as in the single-phase type with this exception: with the potential circuit of one element disconnected, double load (current) is applied to the other element when adjusting full-scale as normally each element would indicate half-scale with rated current and voltage.

When both elements have been adjusted separately for full scale, they are bucked against each other by reversing the leads of either current coil and shifting one of the moving coils to be sure that each element is adjusted exactly alike so that errors of indication on unbalanced loads are reduced to the minimum. If it is necessary to shift the moving coils, the full-scale point and balance may require readjustments as outlined before. See Fig. 12 for typical connections and circuit for calibrating a polyphase wattmeter.

As with the single-phase wattmeter, when all preliminary adjustments are completed, the coils should be made tight on the shaft, permanent resistors should be cut in, balance should be checked and the instrument calibrated with a comparator or standard of known accuracy.

To ascertain the full-scale capacity of a wattmeter, connected to the secondaries of transformers with known ratios, the following information should be helpful.

Assume the scale marking of a wattmeter to be 0 to 300 kw. and it is calibrated for use with transformers having 400 to 5 current and 500 to 100 potential transformer ratios. From the above we would have, $400 \times 500 = 200000$ watts per element or 400000 watts for both elements. Since the nominal secondary transformer outputs are 5A. 100V., we have $5A \times 100V = 500$ watts. Then 400KW::300KW::500W :x or $400x = 150000$ and $x = 375$ watts, full scale of the instrument, with current coils in series and potential coils in parallel on a single-phase line.

Single-phase connections for testing both single and polyphase wattmeters are shown in Figs. 11 and 12 with explanation of same.

*The general rule for ground test is to apply double nominal voltage rating plus 1000 volts for one minute.

Zero-center wattmeters are tested and calibrated on single-phase circuits, the same as zero-left instruments except when checking the full-scale left position, the leads to the current coils are reversed.

A typical connection arrangement for calibrating three-current-coil wattmeters is shown in Fig. 13. In this type of wattmeter, the lower halves of the series elements are connected in series to measure the current in one leg of the line, while the upper parts of each series element are connected to measure the current in the other two legs. In

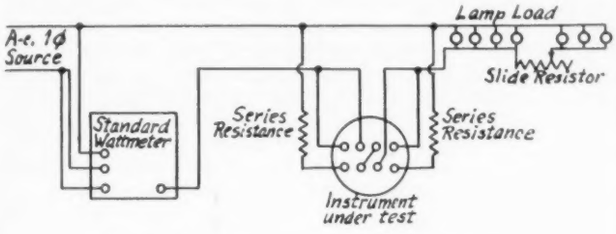

Fig. 12. Test connections for a polyphase wattmeter.

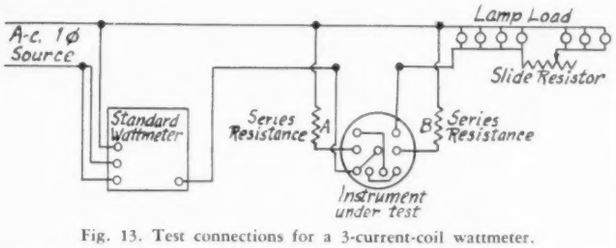

Fig. 13. Test connections for a 3-current-coil wattmeter.

making calibration adjustments on this instrument, one voltage element should be disconnected (lead *A*) and with the current coils in series as shown in Fig. 13 adjust the resistor in the *B* circuit to read full-scale with double load in the current coils. To calibrate the other element, connect lead *A*, remove lead *B* and proceed as before. To buck the elements, interchange leads *A* and *C*, and adjust as in the zero-left wattmeters. When the foregoing tests are completed, reconnect the wattmeter as in Fig. 13, apply single load and check. If all adjustments have been made correctly, full-scale will be correct.

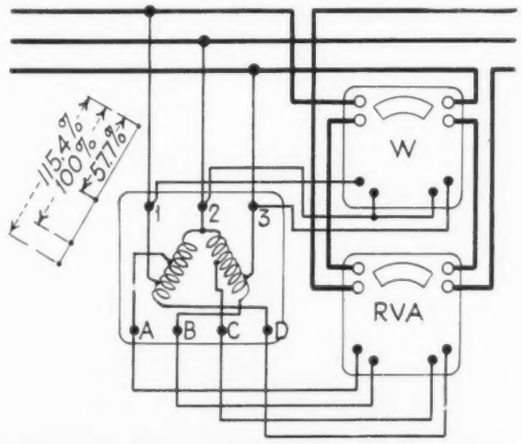

Fig. 14. Direct measurement of reactive volt-amperes with wattmeter and phase-shifting transformer. R.V.A. compensator wattmeter and reactive volt-ampere meter on same load. This arrangement is suitable for either electrodynamic or induction-type wattmeters. (From "Industrial Electrical Measurements and Control" by Borden and Behar.)

Methods of measuring reactive volt-amperes with wattmeters are shown and explained in Figs. 14 and 15 and the captions under them—reproduced and copied from "Industrial Electrical Measurements and Control" by P. A. Borden and M. F. Béhar.

The testing and calibration of reactive volt-ampere meters or varmeters is similar to that of polyphase wattme-

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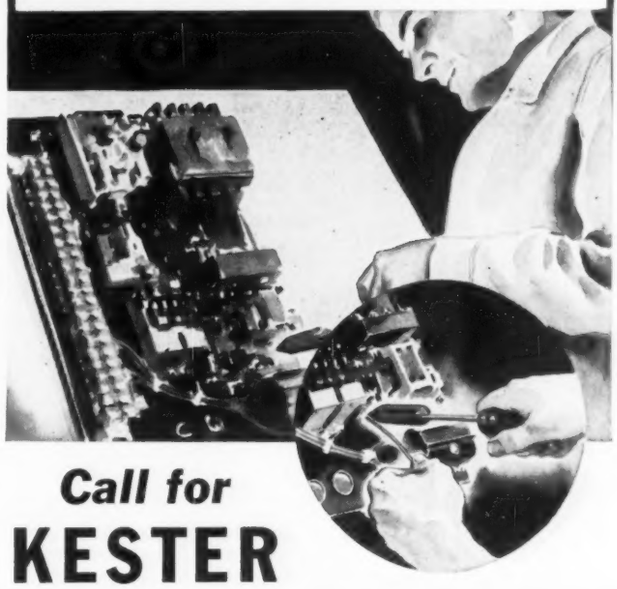

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ters and a phase shifting transformer is used in the voltage circuit connections to produce an out-of-phase component so that the wattmeter indicates reactive power.

The polyphase varmeter is similar to the polyphase wattmeter except for the phase-shifting transformer used. (Some beginners might do well to read Chapter V on Instrument Transformers before going on.) The phase shifter is in reality an open delta transformer, as shown in Figs. 14 and 15, and is used with a standard polyphase wattmeter to

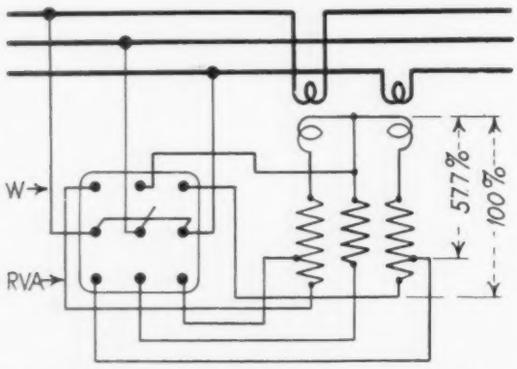

Fig. 15. Direct measurement of reactive volt-amperes with modified series resistors. Total resistance of each voltage element of wattmeter must be brought to a common value *R*, calibration and balance between elements being effected mechanically. Taps are brought out at 57.7 *R* points on series resistors, and a third unit of resistance value = 57.7 *R* added. Throwing the switch in the diagram to the UP position causes the instrument to read watts, and the DOWN position reactive component. This method suited only to use with instruments having a high ratio of resistance to inductance in the potential circuits. (From "Industrial Electrical Measurements and Control" by Borden and Behar.)

measure and indicate reactive power. The function of the phase-shifting transformers is to shift the voltage impressed on the potential coils of the instrument, by an angle of 90 degrees. The vectors shown in Fig. 16b are based on a phase rotation of 1-2, 2-3, 3-1. If the phase rotation is reversed leads *A* and *B* must be reversed, and leads *D* and *C* must be reversed. The phase shifter test consists of connecting to a 100-volt line and checking taps, 57.7, 115.4 and 100% of each winding or of line voltage. (See Fig. 11 of Chapter V on Instrument Transformers.)

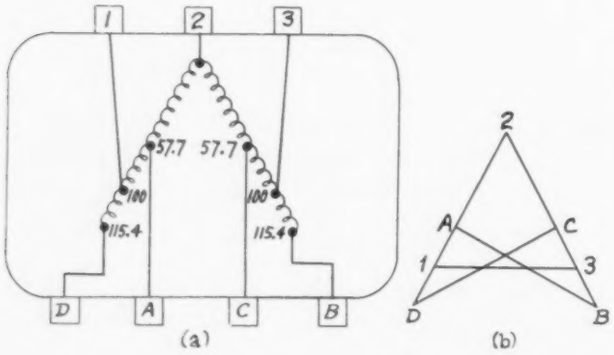

Fig. 16. Showing internal connections and vectors of a phase-shifting transformer.

Phase-shifting transformers are not required to measure reactive volt-amperes on a two-phase, four-wire circuit as the two phases are always 90 degrees apart. By transferring the potential connections from each phase to the instrument, a reactive volt-ampere indication will result.

The use of a phase-shifting transformer or some similar device is necessary to measure reactive volt-amperes of a single-phase circuit. By shifting the voltage across the potential coil 90 degrees from its connection for measuring watts, a single-phase wattmeter may be calibrated to indicate reactive volt-amperes directly.

Induction Type

The induction type wattmeter differs from the electrodynamic type wattmeter in application, in that it can be used only for alternating-current circuit measurements. The fact that the electrodynamic type wattmeter can be used for both a-c. and d-c. measurements is one of the reasons why it supersedes the induction type wattmeter. Other reasons are shown in the comparison chart in Chapter IV.

Construction:

The construction of the induction type wattmeter electromagnet is similar to that of the induction type ammeter and voltmeter, except that it has a voltage coil on each leg of the magnet and a current coil on each pole of the magnet instead of the auxiliary coils of the ammeter and voltmeter. See Fig. 17. A power factor or compensating loop is also a part of the electromagnet, serving to compensate for phase angle difference between the current and voltage circuits. The moving parts of the induction type instrument consist of the phosphor bronze spiral springs, a shaft with hard steel pivots, a channel constructed pointer, and an

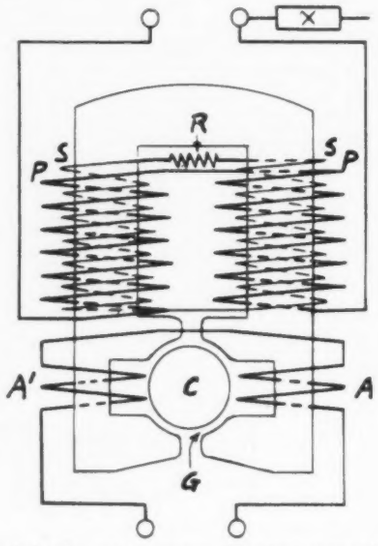

Fig. 17. Induction type wattmeter. Showing construction features of stationary element.

aluminum drum. The stationary parts are of cast iron frame and base, the 320-degree paper dial with a brass back plate, a pressed steel open faced cover, a permanent magnet, the electromagnet and the necessary terminals for mounting and connecting the instrument to an electrical circuit. Fig. 17 shows the internal and external connections of the induction type instrument and resistors or reactors.

Principle of Operation:

The induction type wattmeter, like the induction type ammeter and voltmeter, can be used only on alternating-current circuits of the frequency on which the instrument is calibrated. The fundamental principle of operation is generally similar to that of ammeters and voltmeters of this type. The operation is dependent upon the interaction of fluxes of the inducing and induced currents. The inducing current is the resultant of the current of the voltage coils and the current of the current coils. The induced current is that current which flows in the aluminum drum or the moving element. The quadruture field of this instrument is obtained as a space displacement, having the straight magnetizing field due to the current coils. High sensitivity is an outstanding characteristic of this instrument. It is due to the high torque-to-weight ratio: there are no moving coils and, therefore, no conductors necessary to conduct current to and from the moving element. The aluminum drum or moving element is light but strong—features which give both sensitivity and ruggedness.

Electromagnetic damping is used in this instrument, the

effect being produced by a permanent magnet and the aluminum drum.

The controlling force opposing the electrical torque is produced by a spiral phosphor bronze spring.

This type of wattmeter is made in switchboard and portable forms, the portables having a wooden case instead of the iron and also having a mirror on the scale to prevent parallax errors (errors in reading the scale due to the operator changing his position). Both the portable and switchboard forms are affected by temperature, having a self-heating error. Frequency and external fields of the same frequency, also affect these instruments. Both forms are direct-reading, having full glass front cases and 320-degree scales. The polyphase wattmeters consist of two single-phase elements having a common shaft for the moving members.

Calibration and Test:

Before calibrating the induction type meter, a preliminary inspection is given to prevent trouble in testing due to improper balance, wrong end play, friction, spring convolutions touching, loose connections, broken wires, shorted coils, etc.

A check should be made to see that the pointer does not move when either voltage or current is on alone. A short length of small gage copper wire should be soldered to the open leads of the power factor loop of each element, to be used to make small power factor adjustments. Apply rated load to the instrument to check polarity at unity power factor.

Adjust zero power factor of each element separately by connecting the current coils and voltage coils to different phases of a two-phase four-wire circuit (90 electrical degrees displacement). At zero power factor the pointer should rest at zero. If the pointer moves from the zero position, open the air gap of reactor to raise pointer or close air gap to lower pointer indication.

Bucking of the three-phase wattmeter is obtained by reversing one field, and shifting drum on shaft until the pointer indicates zero at rated load. With the proper standards for comparison the instrument is calibrated by changing spring after instrument has been in circuit at least ten minutes.

Mechanical Inspection:

The cover and base should be properly fitted and have a good clean finish. All screws and nuts should be tight and not marred or burred in any way. Screw in spring clamp should be tight, as should be the set screws in the drums and the nuts holding the damping magnet. Bumpers should be properly adjusted and the rim in the cover should be flush with the face of the dial. All soldered joints should be tight and of good appearance. The dial should be clean and free of all blemishes. The instrument should be clean, polished and free of any excess material lodged inside of the meters. Thumb screws on terminals should screw in and out freely and be tight when screwed down. In general the instrument should have good workmanship.

A ground test of 1500 volts should be given from all terminals to the frame of the instrument and 500 volts between the voltage and current windings.

Maintenance

Barring accidents, rough handling or misapplication, the present-day instrument should not require more attention than the normal periodic checking. Unfortunately, however, defects do result from these causes, making it necessary to repair the instrument. In view of this, the list of possible defects given should aid the repair man in locating the causes of the faults and in making corrections.

When a wattmeter fails to indicate, it is probably due to one of the following:

element sticking,
open-circuit in coils or resistors,
short-circuited current or potential coils,
no external circuit or
(in the polyphase instrument) elements may be bucking.

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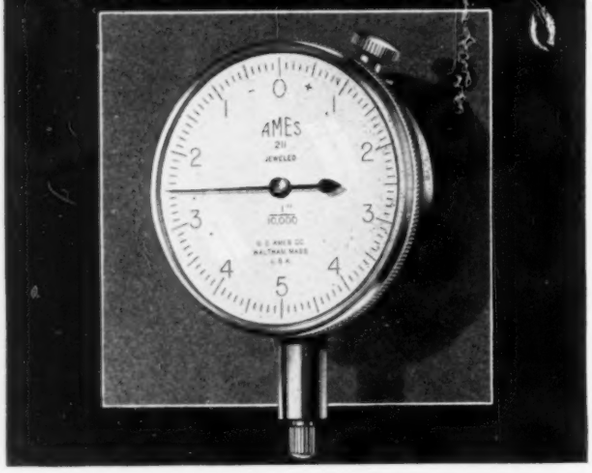

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To check for element sticking, turn the zero adjustor button with a quick flip and note if the pointer moves freely. *Never strike the instrument to relieve element sticking* as this may ruin the pivots and jewels or it may distort the damping vane and cause friction. If this procedure does not free the element the cover should be removed from the instrument and further investigation made. The points to inspect for sticking are pointer on bumper, moving coil on adjacent parts, cross or tail pieces on bridge supports, stationary coil or zero adjustor and damping vane in damping chamber.

Before opening the instrument, however, a careful check should be made to ascertain that the supply circuits are not dead. This test and the electrical tests that immediately follow can be made efficiently using a neon test lamp. If the circuit under test is not open, and instrument connections to the line are properly made, each part of the instrument proper should be tested separately until the fault is located. Using the neon test lamp, a check of the potential circuit should follow by first connecting the lamp across the series resistance and then across the element, with the full voltage applied to the instrument. If the resistor is open, the lamp will light and the instrument will show some indication. If the lamp does not light on this test, the fault is in the instrument element and can be verified by checking with the lamp. If the lamp lights when connected across the element, the element is open, if it does not light, the element is shorted.

The series circuit of the instrument can be checked by connecting an ammeter in series with the current circuit. If the current coils are open, the ammeter will not indicate. If the current coils are shorted the ammeter will indicate the line current. As a further check to be sure the open is in the coil and not in the series circuit, connect the standard in parallel with the current coils. If the ammeter indicates full line current, the coil is open. If no indication results, the fault is in some other part of the series circuit.

In making the above test on the current circuit, always short-circuit the *secondary* of series transformer while making connections, as a dangerous voltage may build up at the open.

A shorted or partly shorted resistance will be evidenced by an abnormally high indication of the pointer. Partial short circuits in the current or potential coils will result in a low reading.

Low readings may also be caused by loose connections that produce high resistance contacts.

In polyphase wattmeters, each element should be checked separately for partly shorted coils. This test is made as outlined in the discussion of tests.

When current and voltage are applied to a polyphase wattmeter and no indication results, the elements may be bucking. That is, the connections may be so made that the polarity of one element is such that it reads forward and the other element reads backward, each neutralizing the effects of the other. To check for this condition, short the current coils of one element and note if the pointer moves either forward or backward. Reversing the current connections of the element that reads backward will correct this condition.

If single-phase instrument stationary coils are removed or replaced in the course of repairs, they should be carefully checked to be sure that the polarity of each coil is such that their fields are not opposing. If the fields of the two coils are opposing the resultant field will be zero or nearly so and no indication is the result.

The following are a few of the important points to check within the instrument when erratic or low readings are noted.

Grounding of the lower pigtail connection of the moving coil to the element shaft will cause a complete short-circuit of the coil—hence no reading on a single-phase instrument. If one coil of a polyphase wattmeter is grounded as above, the wattmeter will indicate only the wattage of one element.

Spring convolutions sticking together or caught on some adjacent part will result in lower readings due to an in-

crease in spring torque. This also produces erratic readings and apparent friction.

Change of balance affects the calibration at different parts of the scale as, for example, shifting of the tail weight away from the pivot results in lower indications on the upper part of the scale and higher indications on the lower part of the scale. Balance changes may result from loose balance weights shifting, warping of moving coils, shifting of coils or pointer and bending of parts on the moving element. As a means of ascertaining whether calibration changes are due to balance, the instrument may be checked in the face-up position: the balance then has little or no effect on the movement of the element.

As with all other indicating instruments, *friction* is one of the worst enemies of the wattmeter. This fault in the wattmeter results from many of the same reasons already outlined in previous chapters and some others inherent only in this instrument. A few of the possible causes of friction in this instrument are:

defective pivots and jewels,
damping vane rubbing in chamber,
damping disk rubbing on magnet,
moving coils touching stationary parts,
spring convolutions touching each other or adjacent parts,
lint on moving coil dragging on adjacent parts,
moving coil connection wire loose around shaft touching stationary coils, etc.

Pivots and jewels are probably responsible for more friction in an instrument than any other items. Flat pivots (due to vibration, insufficient end play, shock and rough handling) are a common cause and the pivots therefore deserve close inspection when friction is present. Cracked jewels, dirt in the jewel, loose jewel mounting and improper jewel adjustment are also points of major importance when checking for friction.

Pointer or balance arms touching adjacent parts should also be looked for if friction is present. If the pointer is rubbing on the dial and bending of the pointer is necessary, the top jewel screw should be loosened before attempting to make bend. This precaution is necessary so that the top pivot will not be ruined by upward pressure against the jewel while bending the pointer. If the pointer stops at about mid-scale and will not deflect further, check to see that the tail weight or arm is not hitting the zero adjustor pin.

The *end play* in most instruments is only a few thousandths of an inch and must be held to this close dimension. If too great an end play exists, the moving parts such as the damping vane will tend to drag on adjacent parts and cause interrupted or jerky movement of the pointer. Insufficient end play causes the element shaft to bend and hence produce variable indications.

In repairing or recalibrating a wattmeter, the following suggestions may be helpful in preventing trouble in the instrument after it is placed back in service.

Don't overheat coils when making single element adjustments of the polyphase wattmeter; if the double current is left on too long it may cause defects in the insulation.

If shifting a moving coil is necessary, be sure that the connecting lead (coil to spring) is not loose around the shaft and touching the stationary coils.

When shifting or bending of moving parts is required while making repairs, the instrument should be either heat-treated or allowed to stand for a reasonable time to stabilize the parts. If equipment is not available for heat treating, and the instrument must be placed back in service as soon as possible, rechecking of the instrument after a few weeks in service is suggested to be sure that mechanically strained parts have not reset themselves, affecting calibration.

In some of the older designs of wattmeters, the manufacturing variations place the electrical axis of the coil unsymetrically about the movement. This means that the stationary coils, if removed, must be replaced in their original position to prevent distribution differences in the two elements, resulting in inaccurate measurements of unbalanced

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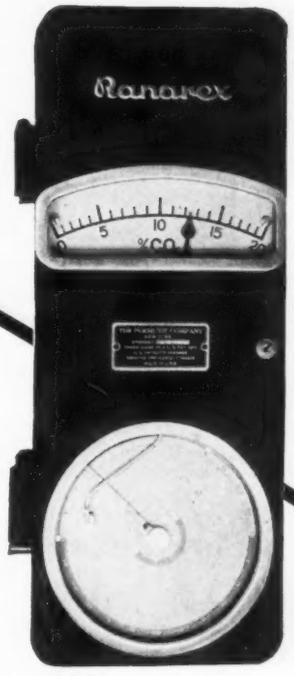

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three-phase systems. To adjust for this conditions, a suggested method would be to place shims of insulating material between the stationary coils and the element frame.

The final check of a wattmeter, before placing back in service, should always be made with the metal cover attached, as *the calibration is affected by the cover.*

If the moving element is removed from the instrument, be sure that the damping chamber is free of dust, dirt and other foreign material, otherwise friction is inevitable due to the small clearances of the vane in the chamber.

Where bumpers are used, be sure that they are properly set to take the shock of the moving element when overloads occur. Setting to prevent the pointer from passing over the bumper and sticking is also an adjustment that should be carefully made.

When placing a wattmeter in service, check instrument coil capacity with known facts as to voltage and current capacity of the circuit to avoid damage to the instrument due to overloading. Also see that the required potential transformers, resistors, and current transformers are in place before throwing switches.

ACCESSORIES

Auxiliary parts used with wattmeters are the torque compensator, series resistor, potential transformer and current transformer. All these accessories may be used to extend the range of the wattmeter.

The series resistor unless connected within the instrument, is usually enclosed in an iron box having screen type sides as in Fig. 18. This arrangement shields the resistor from external effects, and gives good ventilation for dissipating the heat generated within the unit.

Transformers are discussed in Chapter V.

CHAPTER IV

BRIEF SUMMARY OF A-C. TYPES

Following is a comparison of the a-c. instruments we have studied:

Characteristic	*Moving Coil*	*Moving Iron*	*Induction*
Initial accuracy	Highest	Good	Good
Ratio of torque to weight	Good	Better	Best
Sturdiness	Delicate	Not delicate	Rugged
Permanence	Good with care	Satisfactory	Best
Frequency errors	None	Slight	Large
Temperature errors	Slight	Slight	High
External fields	Heavy shield required*	Heavy shield required†	Slightly affected
Scales	Short	Short	Long
Repairs	Fair	Easy	Simple
Damping	Good	Good	Good

*Affected by stray fields of same frequency only.
†Affected by any a-c. or d-c. field.

From this chart of characteristics we have the following summary to bear in mind:

Moving-iron Electromagnet type Instrument.

This type has a good initial accuracy of calibration and is fairly free from frequency and temperature errors. The ratio of torque to weight is sufficient. Are easy to repair and are affected by external fields of both a-c. and d-c. circuits unless shielded heavily. It has a scale of approximately one hundred degrees.

Moving-coil Electrodynamic Instruments.

Highest initial accuracy of calibration and freedom from frequency or temperature errors. A lower torque-to-weight ratio. Delicate and difficult to repair. Unless heavily protected by a magnetic shield, is affected by external fields of the same frequency. Like the moving-iron type it has a short scale.

Induction Type Instruments.

Has a good initial accuracy and continued accuracy. The ratio of torque to weight is high. Instrument is rugged due to the simple movement. It is easy to repair. Unlike the moving iron or dynamometer types it has a long scale. Calibrated on one frequency and errors enter when used on other frequencies. Affected by external fields of same frequency only.

CHAPTER V

INSTRUMENT TRANSFORMERS

Instrument transformers have two purposes: to step the current or voltage down to a value that may be measured on a standard capacity instrument (usually 5 amps-115 volts) and to insulate the instrument from the high voltage of the line.

Instrument transformers are usually smaller than most power transformers but otherwise are similar in construction. This statement of course applies to the usual dry type of transformer as illustrated in Figs. 1, 2 and 3. For high voltages (kilovolts), large oil types are used—some of them installed outdoors, like the big power transformers.

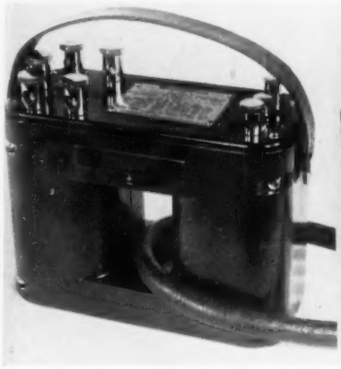


Fig. 1. Current transformer showing one turn of cable linking transformer. Ratio of transformer is dependent on the number of linkages serving as primary winding.

Fig. 2. Potential transformer, tap type, showing connection diagrams of various ratio settings.

As a first step in refreshing our minds as to the principle and purpose of the transformer, let us look over the definition of this device.

A transformer is a piece of apparatus without continuously moving parts, which, by electromagnetic induction, transforms alternating or intermittent electric power in one circuit into alternating or intermittent electric power in another circuit, usually at different values of voltage and current. (A.I.E.E. Standard Definition.)

This general definition holds for both current and potential transformers. The potential transformer is for the pur-

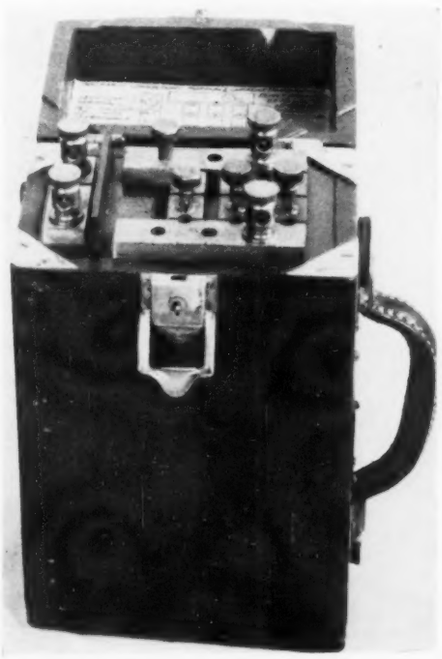
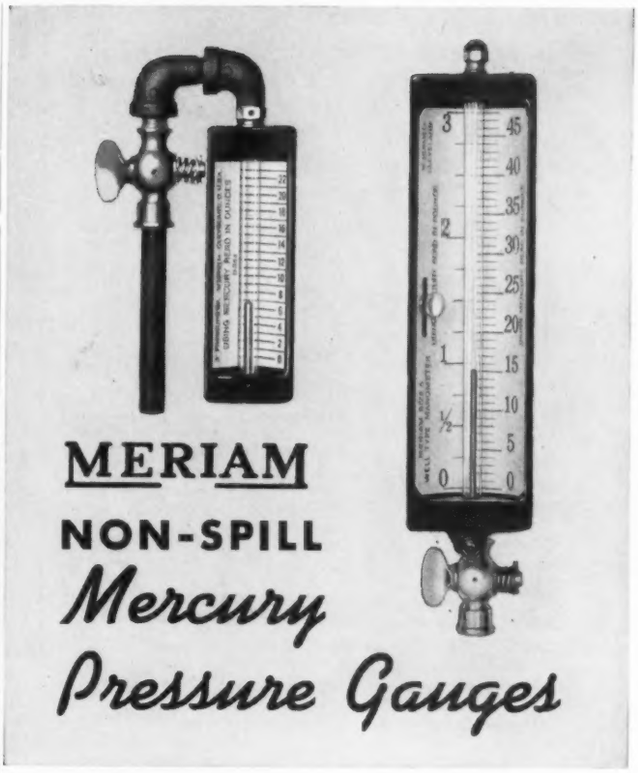


Fig. 3. Plug type transformer showing primary and secondary terminals and plug plate with plugs inserted for definite transformer ratio.



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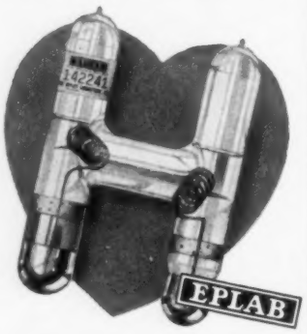

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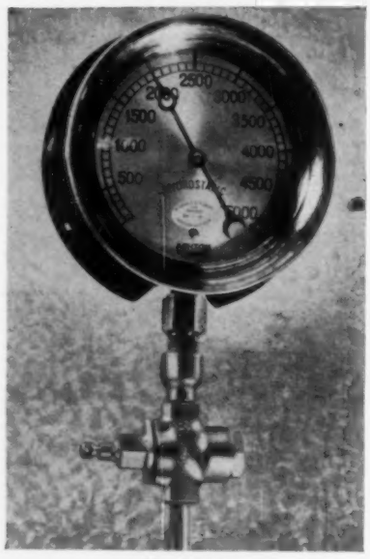

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pose of raising or lowering the voltage to be measured while the current transformer is used to raise or lower the line current. The definitions below should suffice as a review of this subject to clarify our thoughts as to the purpose of each type of transformer.

A Current Transformer is one which is intended for measurement or control purposes, and designed to have its primary winding connected in series with a circuit carrying the current to be measured or controlled. (A.I.E.E. Standard Definition)

A Voltage Transformer is a transformer intended for measurement or control purposes, which is designed to have its primary winding connected in parallel with a circuit, the voltage of which is to be measured or controlled. (A.I.E.E. Standard Definition)

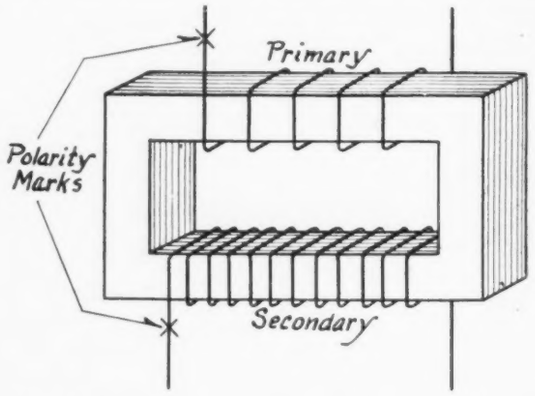

Fig. 4. Showing typical construction of a transformer with primary and secondary polarity markings.

In general, the constructions of the current and potential transformers are similar (see Fig. 4) except for the size of wire and the number of turns in each. The voltage transformer is wound with a large number of turns of small wire while the current transformer wire is large and the number of turns relatively low.

The three general types (forms) of instrument transformers are the plug, tap and through types—see Figs. 1, 2 and 3. Potential transformers are usually of the tap type while current transformers may be any of the three kinds.

The plug type (Fig. 3) is one in which by a plugging arrangement, the ratio of primary to secondary turns is changed, hence ratio changes of primary to secondary current or voltage values.

In the through type current transformer, the ratio is changed by the number of turns looped through the open core of the transformer as shown in Fig. 1.

The various ratios of primary to secondary of the tap transformer are obtained by connecting to the tap of the ratio desired. See Fig. 2.

There being many text books covering transformers, it is not our intention to cover this subject fully. A few points on the use of transformers with instruments will serve as a refresher to the reader.

The use of instrument transformers with a-c. instruments has long been a source of trouble to service men due to a lack of understanding of the possible sources of danger.

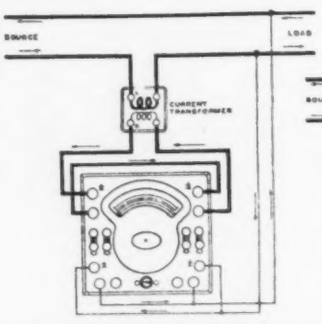

Fig. 5. Instrument connected to line through a current transformer, current coils in series. (Weston diagram.)

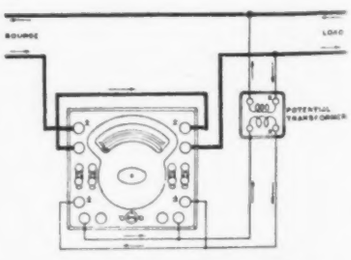

Fig. 6. Instrument connected to load through a voltage transformer, current coils in series. (Weston diagram.)

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I-416 **Rubber Testing Instruments.** Catalog, describes instruments and apparatus for making chemical and physical tests of rubber and rubber-like materials according to A.S.T.M., Federal and other standards. Catalog is available upon application to manufacturer on business or professional stationery. American Instrument Co., 8010 Georgia Ave., Silver Spring, Md.

I-417 **Constant Voltage Transformers.** Bulletin CV-74, 8½" × 11", 22 pages, describes and illustrates transformers which deliver a constant output voltage, independent of transient or continuous variations in supply voltage. Covers construction, operation and applications of transformers. Sola Electric Co., 2525 Clybourn Ave., Chicago, Ill.

I-418 **Lever Switch for Electrical Control.** Bulletin No. 61, 8½" × 11", 4 pages, covers series 4101 heavy duty, multiple contact, positive action lever type switch. Donald P. Mossman, Inc., 6021 N. Northwestern Highway, Chicago, Ill.

I-419 **Electrode-Pressure Gage.** Bulletin GEA-3628, 8" × 10½" 2 pages, describes and illustrates the electrode-pressure gage designed to measure the pressure between the electrodes of resistance-welding machines; will measure electrode pressures up to 4500 lbs. General Electric Co., Schenectady, N. Y.

I-420 **Measurement of Plasticity.** Sheet, 8½" × 10⅞", 2 pages, describes and illustrates the Plastograph to measure and record, in graph form, the plasticity of any material from light viscous substances to unvulcanized rubber. Records consistency, absorption, swelling, mixing requirements, mixing tolerance, breakdown, etc. Brabender Corp., Rochelle Park, N. J.

I-421 **"Supplementary Treatment of Boiler Feed Water."** Bulletin No. 2420, 8½ × 11", 12 pages, discusses supplementary treatment which generally consists in feeding phosphate, sodium sulfite or sodium sulfate in varying amounts. The Permutit Co., 330 West 42nd St., New York City.

I-422 **Temperature Instruments for Plating Operations.** Bulletin B-296, 8½" × 11", 8 pages, describes temperature control in chromium plating with Duplex controller, covers pneumatic recording temperature controller, pneumatic valves, "Rotax" electric controllers and electric motor valves; also temperature instruments for cleaning and rinse tanks. The Foxboro Co., 46 Neponset Ave., Foxboro, Mass.

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I-426 **Instruments for Commercial Vehicles.** Catalog, 6" x 8⅞", 36 pages, describes and illustrates line of odometers, speedometers, recorders, hubodometer, engine revolution counters, tachometers, taximeters and special instruments for measuring and testing purposes. Paul Knopf—Registering Devices, 32-11 39th Ave., Long Island City, N. Y.

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I-430 **"The Ohmite News."** Nov. 1941, 2 pages, contains article entitled "Tapered Windings Decrease Rheostat Size Required." Ohmite Mfg. Co., 4835-41 Flournoy St., Chicago, Ill.

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I-432 **"Cornell-Dubilier Capacitor."** Vol. 5, No. 9, 16 pages, contains article entitled "A Flexible Plug-In Tester," also a number of items on radio service hints. Cornell-Dubilier Electric Corp., New Bedford, Mass.

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Personal safety and safety of equipment are both in jeopardy if transformers are not handled and used properly. This auxiliary apparatus may also be the cause of producing faulty instrument indications if not applied properly or if allowed to become defective.

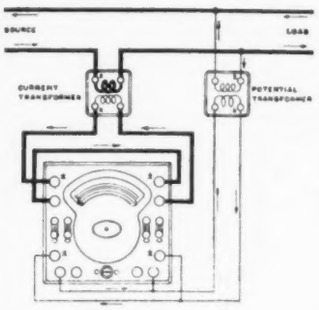


Fig. 7. Instrument connected to load through both current and voltage transformer. (Weston diagram.)

The connection diagrams, Figs. 5, 6 and 7, should suffice as a means of explaining the application of transformers. In making these connections, the few cautions herewith given should be carefully observed for best results.

(1) Follow polarity markings on the transformers so that the instrument will indicate in a forward direction.

(2) Keep current transformer secondaries shorted at all times when making or breaking instrument connections, as a high difference of potential may exist when secondary is opened. This is due to the fact that on open circuit the current transformer acts as a voltage step-up transformer due to the high ratio of secondary to primary turns.

(3) Instrument connections to secondaries of potential transformers should be made only if voltage is known to be of a magnitude that will not damage the instrument.

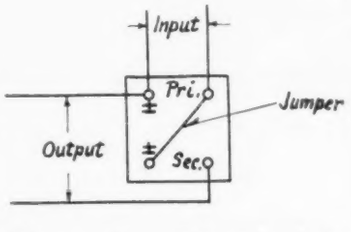
(4) Loose or dirty terminal connections should be avoided as they cause undesirable heating, with resistance which may alter the ratio of the transformers and cause inaccurate readings.

(5) Don't exceed the burden rating of a transformer, as the transformer ratio will change under this condition.

(6) In the plug type transformer, be sure the plugs are securely fitted in the inserts of the ratio plug plate, as loose plugs result in transformer errors and unsteady current.

(7) In the tap type transformer, be sure the instrument is connected to the correct taps before applying current or voltage, so that the instrument will not be damaged by an overload.

Fig. 8. Diagram of connections for checking polarity of potential transformers.
Connect as shown—polarity is correct if input is less than output.



Erroneous polarity markings or the omission of polarity markings of transformers could cause a great deal of confusion and unnecessary work in switchboard wiring. For this reason it is felt that a few suggestions on this subject would not go amiss at this time.

If a transformer requires repairs and the leads are disconnected, the leads should be tagged to be sure they are reconnected correctly. To check the polarity of a transformer, follow the instructions given in captions under Figs. 8 and 9. The usual precautions of not opening the secondary circuit of a current transformer while the primary circuit is energized should be kept in mind.

Polarity markings on transformers as shown in Fig. 10 are for the purpose of indicating the relative instantaneous direction of primary and secondary currents. That is

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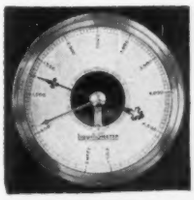

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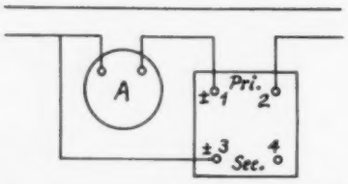

Fig. 9. Diagram of connections for checking polarity of current transformers.
(1) Connect as shown and apply current of a known value.
(2) Short circuit terminals 3 and 4 and note ammeter reading.
(3) Disconnect lead between 3 and 4, connect lead from 4 to 1 and note ammeter reading.
(4) Polarity is correct if current indication in step (2) is less than in step (3).

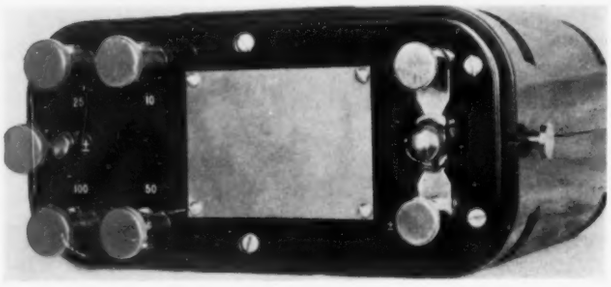

Fig. 10. Showing terminal block of a tap transformer with primary and secondary polarity markings.

when the instantaneous direction of current flow is toward the transformer in the marked lead of the primary circuit, the current is flowing away from the transformer at the marked secondary terminal as in Fig. 11.

Design of modern instrument transformers is such that it is considered unnecessary for indicating instrument work to take account of possible errors of transformation. However, manufacturers may supply ratio error curves for special high-precision measurement purposes. Testing trans-

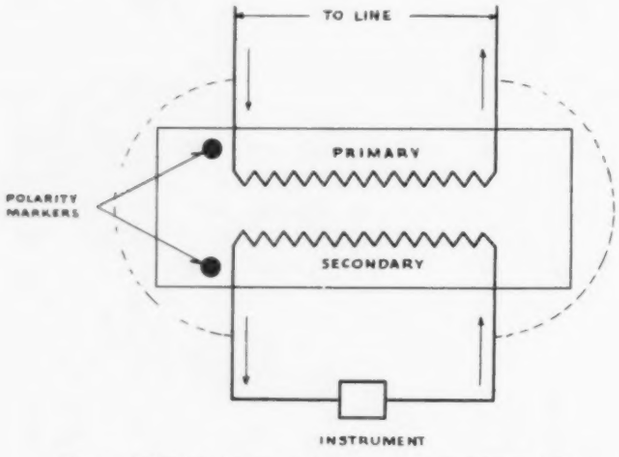

Fig. 11. Schematic diagram of an instrument transformer illustrating the polarity or relative direction of primary and secondary currents at a given instant.

formers for ratio errors involves special laboratory methods and equipment and is beyond the scope of this book which is principally devoted to the upkeep and repairs of electrical instruments.

If through accident it is suspected that the transformer is damaged, the principal things to look for are insulation breakdown and short-circuited turns. Insulation breakdown could be determined with a Megger as outlined in Chapter I, or by means of an over-voltage insulation test between coils or from coils to ground. Short-circuits would be indicated in potential transformers by heating, in current transformers by ratio and hence errors of indication on the instrument. *(To be continued)*

Instruments for H-f. Power

(Concluded from page 393)

kva. reactance, it is necessary to provide power-factor correction by means of capacitors. Since the permeability and resistivity of the induction furnace charge varies with the temperature, the power factor will change and it is necessary to check conditions periodically and make any adjustments necessary. In the case of short-time heating cycles, such as heat treating and hardening operations which require only a few seconds, the varmeter or power factor meter determines the correct value so that successive production can be duplicated.

(2) Automatic voltage regulators used on generators would increase excitation if the power factor became lagging. This could progress to the point of overheating the generator field. If automatic voltage regulators were not used, the kw. input to the load would be materially reduced under the above condition, since the voltage would drop with fixed excitation in an increasingly inductive load. The power factor is therefore important.

Recently the varmeter has widely displaced power-factor meters, as it makes possible closer tuning of the circuit. In the case of light loads, the power-factor meter (which is a position type of instrument as contrasted with the torque-deflection characteristic of the varmeter) is subject to errors due to the low torque developed by the current circuit at light load, allowing the torque of the conducting strips of the moving element to influence the readings. The accuracy of both varmeters and power-factor meters is dependent upon the wave form, a sinusoidal wave being used for calibration. Harmonics therefore will give a discrepancy in the cross check between the volt-ampere reactive product compared with the wattmeter reading. Reactive instruments should therefore be used for control purposes, rather than for exact measurements.

A necessary precaution in audio-frequency measurements is to make certain that instruments with voltage and current circuits have the voltage terminal which is connected to the voltage coil connected also to the low-potential or grounded line. This brings the moving and stationary coils to the same potential level, eliminating capacitive errors which at the higher audio frequencies may be large. It is, of course, conventional practice even at power frequencies to connect the voltage terminal from the resister end of the voltage circuit to the opposite line from the current coil. However, at higher audio frequencies, the effects are so much more pronounced that this point must not be overlooked.

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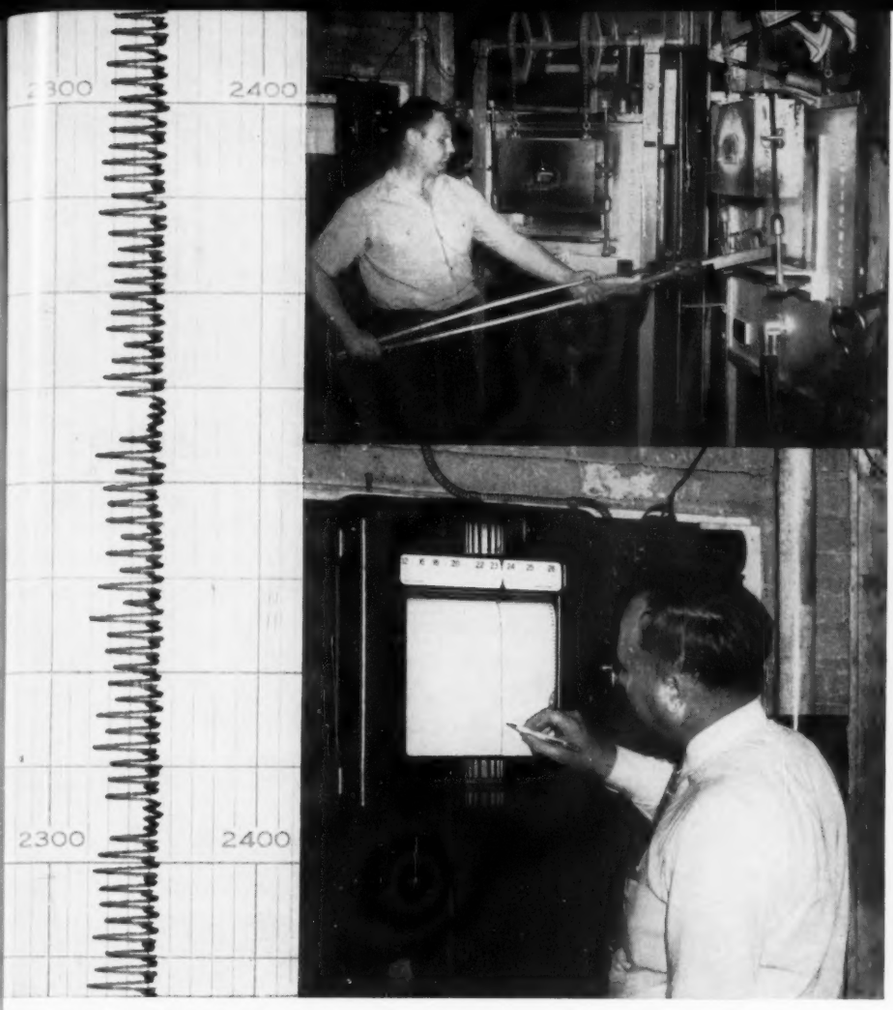

Each "spike" on the Micromax Pyrometer chart at left means that one more batch of milling cutters has gone into the Micromax-controlled heat-treating furnace. Charging is shown in photo at top. Above, the foreman glances at the Pyrometer to see that all is going well.

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After hardening, this die is used by the Gray Manufacturing Co. to stamp their company name on telephone coin boxes.

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The question of how to handle this die in the hardening furnace might well be a problem in many heat-treats. Its original dollar-a-pound cost, for the steel, was of course redoubled several times as highly-skilled die-sinkers labored over it, so that a bit of uneasiness as to furnace operation might well have been expected.

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Heat-treater loading die into Vapocarb-Hump furnace.

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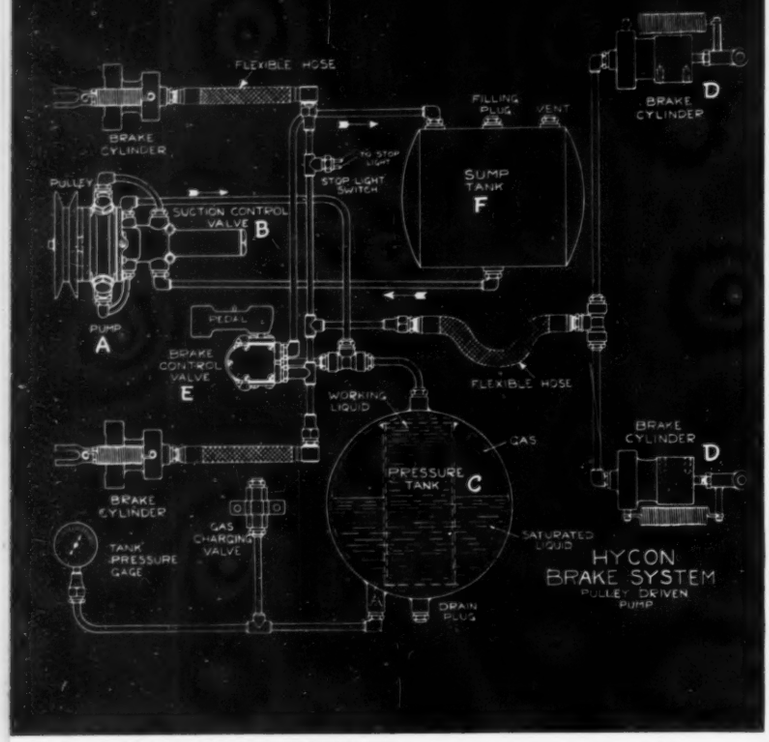

Typical installation with Hycon pump and pressure tank actuating 4 work cylinders

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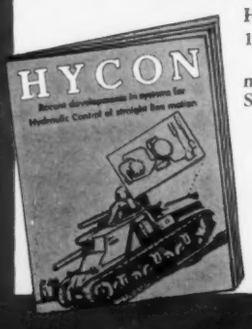

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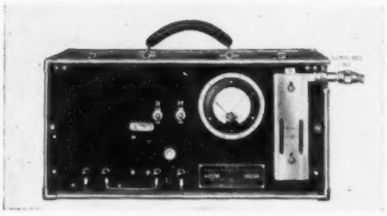

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Operates on same basic principle as the M.S.A. Carbon Monoxide Alarm; starts ventilation motors when the amount of carbon monoxide in the air becomes dangerous, and keeps ventilating equipment operating until the atmosphere is safe. Reduces ventilation and heating costs to a *safe minimum*. We will gladly submit our recommendations; no obligation, of course.

MINE SAFETY APPLIANCES COMPANY

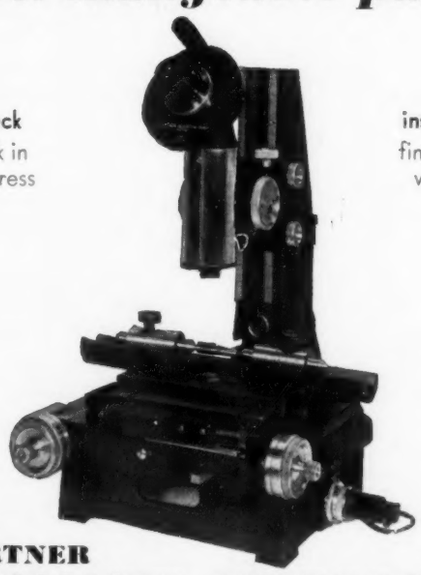
BRADDOCK, THOMAS & MEADE STREETS · PITTSBURGH, PA.

District Representatives in Principal Cities

facilitate production of interchangeable parts

check work in progress

inspect finished work



with the

GAERTNER

TOOLMAKER MICROSCOPE

Send for Bulletin 147

THE GAERTNER SCIENTIFIC CORP.

1211 Wrightwood Ave. · Chicago · U.S.A.

The January Issue

will be in two parts as is the custom since 1938.

As usual, Part Two will be THE INSTRUMENTS INDEX — the annual guide and directory containing: (1) An alphabetical index of instruments, meters, controllers, etc., for measurement, testing, inspection and control—with names of all makers of all types. (2) Descriptive directory of manufacturers. (3) Reviews of recent books on measurement, control, testing and allied subjects.

Part One will be written by you! Authorities on all principal subjects of interest to you are being invited (and, by the way, you personally are invited) to contribute brief summaries of recent advances, trends and interpretations. The general theme is that 1942 will be a turning point. From promises already received, the subjects will be exciting as well as informative.

DON'T RISK MISSING THIS ISSUE!

INDUSTRIAL INSTRUMENT SERVICE

CLAUD S. GORDON CO., Cleveland—Chicago—Indianapolis

3AG FUSE

For delicate equipment, meters, galvanometers, etc., one of hundreds in complete line of Instrument LITTELFUSES and mountings, every type and purpose. Write for catalog.

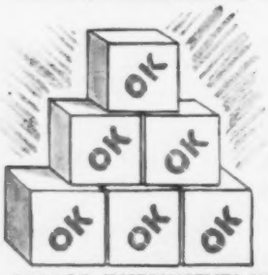
LITTELFUSE, INC. 4759 Ravenswood Ave. Chicago, Ill.

UNCLE SAM KNOWS THIS...

Taylor Instruments are doing **NOT 1 BUT 5** *jobs for defense*

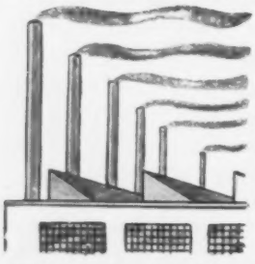
▶ Everything that Taylor makes is made to measure. Every instrument that Taylor makes for Industry is designed to indicate *precisely*, or record *precisely*, or control *precisely*. Taylor-made precision protects Industry's power to produce today. These are the jobs —*not 1 but 5 jobs*—that Taylor Instruments are doing for defense:

TAYLOR INSTRUMENTS HELP MAKE BETTER PRODUCTS



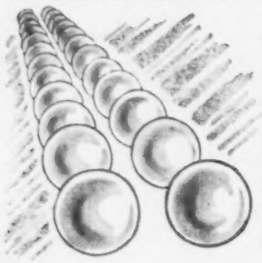
Constant top-grade perfection comes from using Taylor Instruments, because they permit complicated processing operations to be carried on automatically.

TAYLOR INSTRUMENTS HELP SPEED UP PRODUCTION



With Taylor Instruments on guard over industrial operations, insuring automatic precision, products can be turned out faster. Mishaps due to human errors get far less chance to gum up the works.

TAYLOR INSTRUMENTS HELP INSURE UNIFORMITY

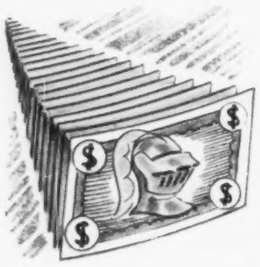


Exact duplication of operations, guaranteeing exact duplication of mass-made products, can be indefinitely carried on if Taylor Instruments are used to record and control those operations with the automatic exactness that human skill can't match.

TAYLOR INSTRUMENTS HELP FREE MANPOWER

Skilled employees in a Taylor-equipped plant do much less "sentry duty" merely watching over operations. They are freed for other more essential work. Taylor Instruments are automatic industrial sentries.

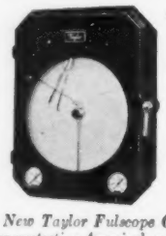
TAYLOR INSTRUMENTS HELP MAKE DEFENSE DOLLARS



GO FARTHER. Uncle Sam is likely to get more of the best for his money from plants using Taylor Instruments. Why? Because, by using Taylor Instruments, these producers often can cut their production, maintenance, and labor costs noticeably and can sell to the Government at lower prices without cutting profits!

Taylor Instruments should be doing these five—not one but five—jobs for you, too. We want you to be getting 100% satisfaction from your present Taylor Instruments, and we're here to see that you do. Perhaps we can suggest ways to improve your instrument performance. We've had plenty of experience in this industrial instrument business. How can we help you most? Taylor Instrument Companies, Rochester, N. Y. Plant also in Toronto, Canada.

Taylor-MADE MEANS BETTER MADE IN AMERICA BY AMERICANS



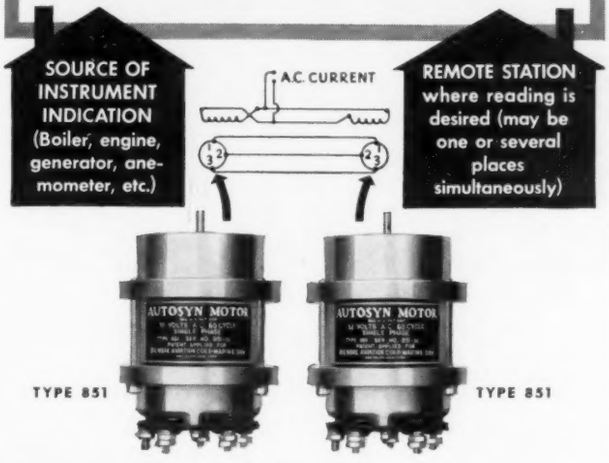
The New Taylor Fulscope Controller protecting America's power to produce with **not 1 but 5** *forms of control.*

Taylor

Indicating Recording Controlling

TEMPERATURE, PRESSURE, FLOW *and* **LEVEL INSTRUMENTS**

How to provide remote readings of almost any instrument—*efficiently, reliably and simply*


SOURCE OF INSTRUMENT INDICATION (Boiler, engine, generator, anemometer, etc.)
A.C. CURRENT
REMOTE STATION where reading is desired (may be one or several places simultaneously)
AUTOSYN MOTOR
AUTOSYN MOTOR
TYPE 851
TYPE 851

Just use a pair of

BENDIX-CORY AUTOSYN

SELF-SYNCHRONIZING SIGNALING UNITS

WHEN it is desirable to be able to read an instrument indication at a distance from its source—perhaps at more than one point simultaneously—Bendix-Cory Autosyn provides the simplest, surest means ever devised. Wired as shown above, the armatures of both "motors" move in unison within an accuracy range of 1° plus or minus (½° on special order). The character of the indication to be transmitted makes little difference—it may be pressure, rate-of-flow, count, dimension, liquid level, voltage, amperage, resistance, temperature. Bendix-Cory Autosyn units are made in several sizes and types. Type 851 (illustrated) produces 2.5 inch-ounces of torque at 90° angular displacement—safe continuous operating torque 1.1 inch-ounces—dimensions 2⅜" x 3$^{15}/_{32}$". One transmitting unit can actuate several variously located receiving units. Autosyns are standard for industrial instrumentation systems. Interested engineers are invited to write—

BENDIX AVIATION CORPORATION
MARINE DIVISION 754 Lexington Avenue, Brooklyn, N. Y.

The All Purpose.... AIR VELOCITY METER

INSTANTANEOUS DIRECT READING

The Alnor Velometer is a versatile direct reading air velocity meter which gives instantaneous readings of the speed of air measured in feet per minute.

The Velometer is ideal for measuring duct velocities and pressures, velocities at grilles or registers. It offers the only convenient and satisfactory instrument for checking drafts, leaks around doors or windows or in ducts, velocities of ceiling outlets and similar air diffusers.

It is made in several standard ranges from 20 F.P.M. to 6000 F.P.M. and up to 3 inches static or total pressure. Special ranges available as low as 10 F.P.M. and up to 25,000 F.P.M. velocity and 20 inch pressure.

Anyone can use the Velometer. No mathematical calculations, no leveling—no timing.

Write for bulletin No. 2448-D

Illinois Testing Laboratories Inc.
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HYDROL METALLIC BELLOWS

● We manufacture bellows and bellows assemblies ready for installation in steam traps, relief valves, temperature regulators, pressure regulators, air valves, and other automatic temperature and pressure controls. Complete engineering service.

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PRODUCERS OF BELLOWS EXCLUSIVELY
SERVING AUTOMATIC CONTROL MANUFACTURERS

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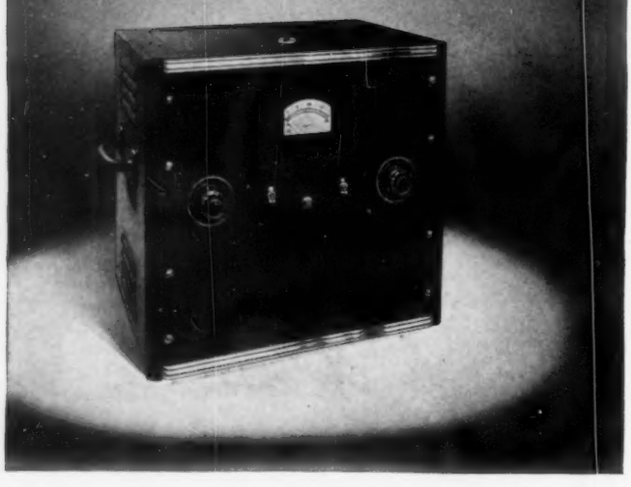
PRESENTING—

the SECO *automatic* VOLTAGE REGULATOR



THE MODERN A-C LINE VOLTAGE CONTROL

This improved type regulator consists of a thyratron tube circuit controlling a motor-driven variable voltage transformer. It maintains a constant output voltage with variations in input voltage or load current.

- CORRECTS FOR WIDE RANGE OF INPUT VOLTAGES—standard 115 volt units, for example, correct for input voltage variations of plus and minus 17.5% of output voltage.
- HIGH EFFICIENCY—has the high efficiency characteristic of the variable voltage auto-transfomer.
- NO INTERNAL MECHANICAL ADJUSTMENTS—does not use a contact-making voltmeter—no critical relay adjustments.
- OUTPUT VOLTAGE AND SENSITIVITY ADJUSTABLE over a wide range by means of knobs on front panel.
- NEGLIGIBLE WAVE-FORM DISTORTION—low exciting current.
- LOW COST PER KVA
- QUICK RESPONSE—time for full range travel is six seconds.
- OPERATION NOT AFFECTED BY LOAD POWER FACTOR.

APPLICATIONS

Maintains correct constant voltage for—

- Manufacturing Equipment
- Electrical Testing
- Electronic Equipment
- Fluorescent Lighting

SEND FOR BULLETIN 163 SI

Available for 115, 230, or 440-volt circuits in capacities up to 75 KVA—single or three phase.

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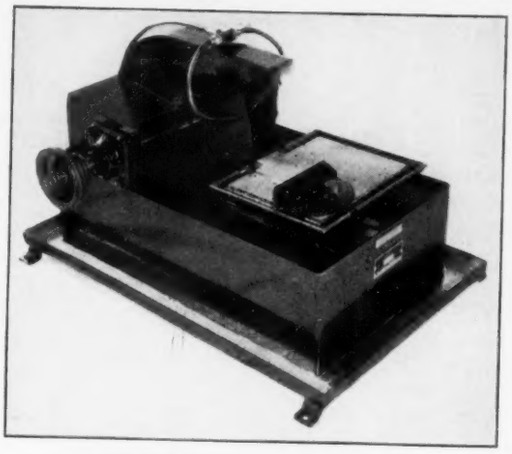
133 HARRISON ST. BRISTOL, CONN.

OPTICAL GLASS FABRICATING MACHINES



CERAMIC CUT-OFF SAW
For Ceramics, Synthetics or Metals

OPTICAL GRINDING MACHINES
AUTOMATIC POLISHING SPINDLES

BAILY VIBRATOR CO.
1539 WOOD STREET PHILADELPHIA, PA.

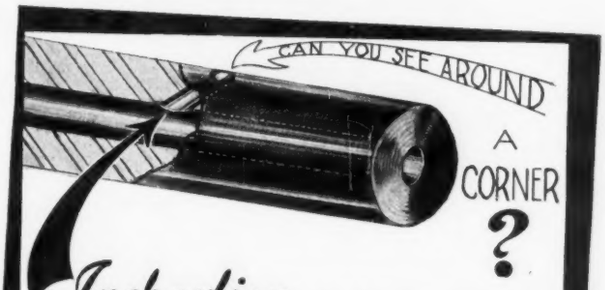
BUT WHAT OF Tomorrow?

"All-out" production to meet today's pyramiding orders does not mean that Triplett has lost sight of the broader requirements of tomorrow. Instead, research and engineering programs actually have been "stepped-up" to assure constant improvements in products and processes; in addition to needed developments in new fields.

Today's demands are important, but the needs of tomorrow cannot be slighted—and are anticipated in never flagging engineering and research developments. You have assurance that in the months and years to come, new Triplett products will serve in expanded fields, where they will merit values and savings for every dollar spent in their purchase.

THE TRIPLETT ELECTRICAL INSTRUMENT CO.
BLUFFTON, OHIO

TRIPLETT



Inspection of hard-to-get-at places now made certain and accurate with the help of

WAPPLER INDUSTRIAL TELESCOPES

Write for our Booklet: "Precision Instruments for the Exacting Inspection of Internal Surfaces."

For prompt action and our recommendations, include drawing of part to be inspected, or preferably the part itself.

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AMERICAN CYSTOSCOPE MAKERS, Inc.
FREDERICK C. WAPPLER, Pres.
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This Gage has *Real* GUTS

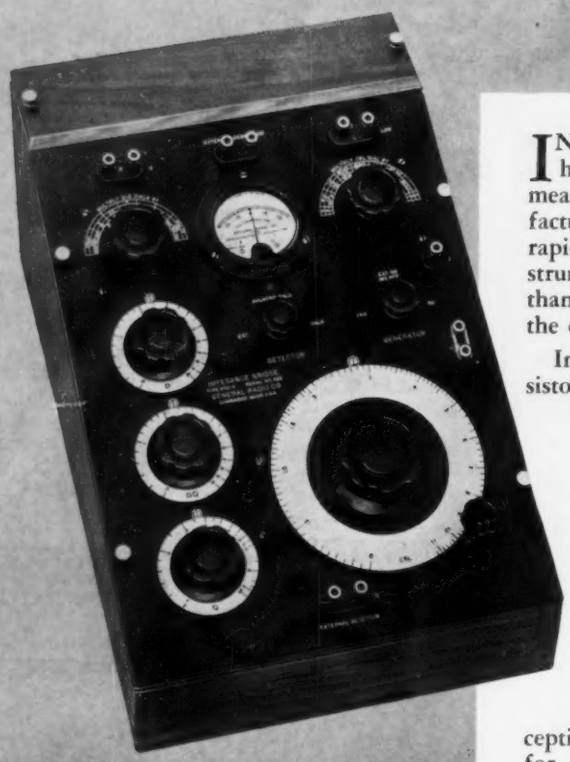
IT can take it! This diaphragm draft measuring unit is the real "insides" of the Hays Draft Gage. Made of colon leather, a tough intestinal membrane, it withstands tremendous pressure or suction, yet is so sensitive that it accurately measures increments of only .0025 of an inch water.

Hays pioneered this dry type of Draft Gage which is promoting better combustion in thousands of boiler rooms. Send for the Hays Catalog which describes its efficiency. Write to 925 Eighth Avenue, Michigan City, Indiana.

The HAYS CORPORATION
SINCE 1901 — COMBUSTION INSTRUMENTS AND CONTROL — MICHIGAN CITY, INDIANA, U.S.A.

MAKING INSTRUMENTS DIRECT READING

with VARIABLE RESISTORS



Type 650-A Impedance Bridge, *direct-reading* over these ranges:
Resistance: 1 milliohm to 1 megohm
Capacitance: 1 micromicrofarad to 100 microfarads
Inductance: 1 microhenry to 100 henrys

The cam on the CRL potentiometer. The contact arm is not connected directly to the potentiometer shaft, but turns freely on it. At the outer end a spring is pressed against a follower which rides on the cam. The cam follower rocking up and down on the cam changes the angular position of the contact arm and the scale. Adjustment of the eight screws will take up all differences between individual potentiometers and the master potentiometer which itself is an average.

IN RESEARCH and production testing the convenience of having instruments read directly in the quantities they measure has been appreciated for some time by the manufacturer and the user of electrical measuring instruments. So rapid have been the improvements in most direct-reading instruments that they now have considerably greater accuracy than similar units manufactured several years ago without the direct-reading feature.

In general, direct-reading scales are used only with resistors and capacitors; the accuracies obtainable are high, frequently as great as 0.1% of full-scale. In order to maintain high accuracy in a direct-reading instrument, *constant* fractional accuracy must be obtained and the rate of variation of the unknown should be logarithmic. In any *linear* scale the fractional accuracy decreases directly with the quantity varied.

The circuit used with any direct-reading instrument has to be chosen so that the magnitude of the variable element is proportional to the unknown.

One of the most interesting examples of a direct-reading instrument is the Type 650-A Impedance Bridge. This bridge measures five quantities over exceptionally wide ranges with the following *maximum* errors: for resistance, 2%; for capacitance, 2%; for inductance, 10%; for dissipation factor (R/X) 20% and for storage factor (X/R) 20%.

For the measurement of so many different quantities and for the very large ranges obtainable from this bridge, four circuits and a number of multipliers are selected by two multi-position switches. The balances are obtained by the use of two of the four variable resistors.

The semi-logarithmic scales on the four dials . . . the CRL, D, DQ and Q dials . . . are direct-reading. The potentiometers used with these dials are wound on tapered cards. The scales can be made direct-reading either by hand calibration of each point to fit the irregularities introduced by variations in wire size and spacing, or these irregularities can be controlled to fit a pre-engraved scale.

Originally the CRL dial of this bridge was hand calibrated with every line set to its proper resistance value. Later, the calibrations on a production lot were averaged and a master constructed. From this master calibration, other dials were engraved on a pantograph engraving machine. These dials are now photo-etched. In the quantities in which this instrument are now manufactured, it has proven much more economical to provide the CRL potentiometers with the photo-etched dial scale and to compensate for irregularities by means of a flexible cam, than to engrave each dial separately.

Many other General Radio direct-reading instruments use resistors as the variable element. The dial scales are calibrated in a manner similar to those on the Type 650-A Bridge.

GENERAL RADIO COMPANY
Cambridge, Massachusetts

YES . . . it's done with mirrors

. . . AND NOW EVEN CELECTRAY'S GREATER SENSITIVITY IS STEPPED UP 4 TIMES!

Heretofore, it was necessary to buy a potentiometer and an extra galvanometer to attain this higher sensitivity. While CELECTRAY has always given Industry greater sensitivity, now, by adding mirrors to CELECTRAY's reflecting galvanometer, this sensitivity has been increased 4 times. CELECTRAY now offers a new, rugged, economical unit in ONE case—combining the potentiometer and high sensitivity galvanometer.

Where the human element is involved and the need persists to note small changes, use this new TAG CELECTRAY Indicating Potentiometer which provides greater deflections. You'll find savings in original installation and lower maintenance expense, plus the fact that absence of strain on your operator will be a large factor in improved results.

As this new CELECTRAY offers maximum sensitivity, similarly the complete line of TAG's Indicating, Recording and Controlling Potentiometers offers the same matchless sensitivity, speed and adaptability. Learn what they can do for you in lowering operating and upkeep costs, and raising product uniformity. Write for your catalog today.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

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Measurement and Control

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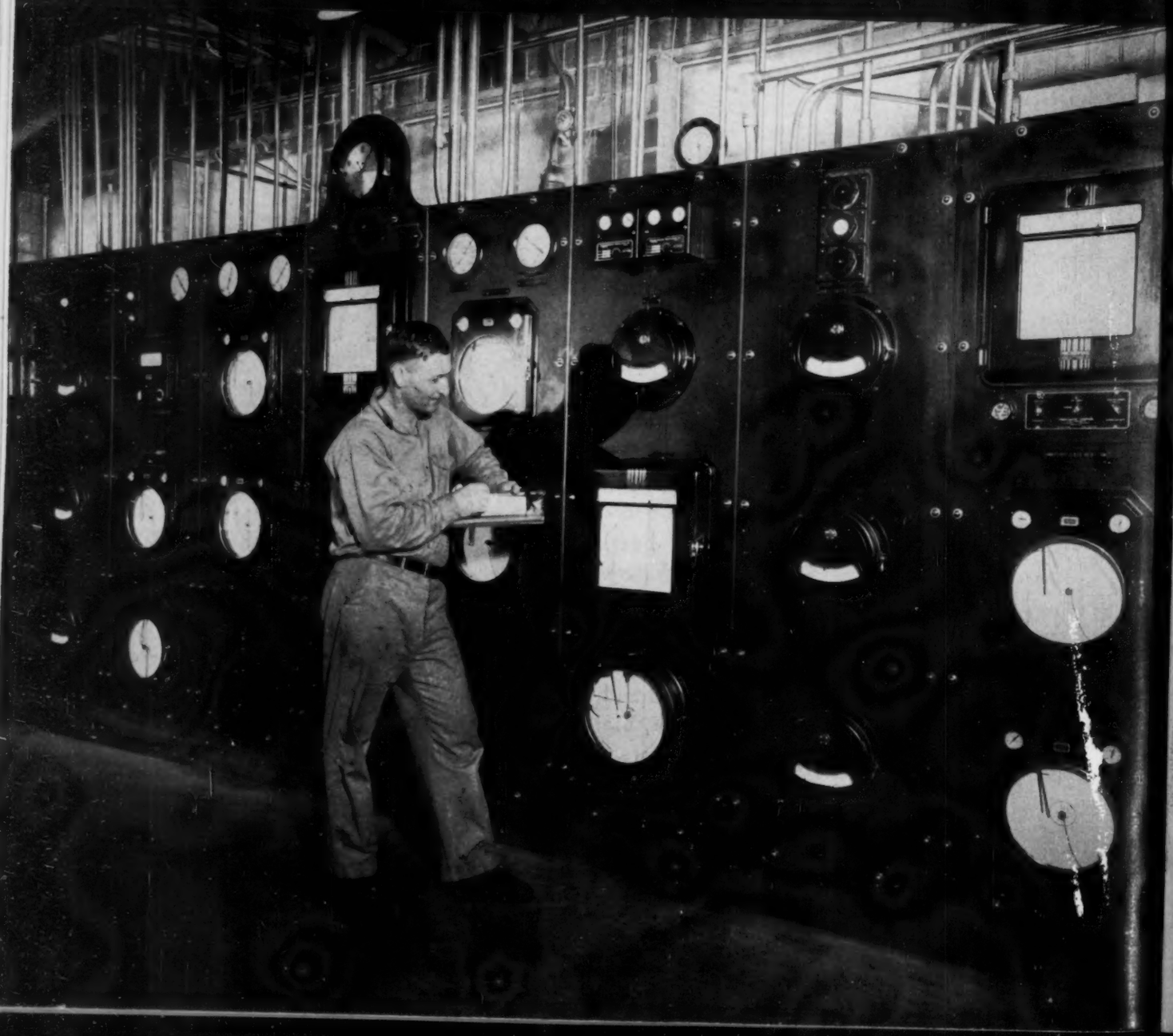

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